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Delaware Univ, Newark Dept of Civil Engineering

Prepared for

Environmental Protection Agency, Washington, D C Office of Air, Land and Water Use

Jun 77

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DEVELOPMENTS AT EIGHTH INTERNATIONAL CONFERENCE ON WATER POLLUTION RESEARCH

Sydney, Australia
October 17-22, 1976

Prepared For

Office of Research and Development
U.S. Environmental Protection Agency
Washington, D.C.

By

United States of America National Committee
for Representation of the United States to the
International Association on Water Pollution Research

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16. ABSTRACT

This report is a critical analysis of formal and informal developments of potential interest to the U.S. Environmental Protection Agency at the Eighth International Conference on Water Pollution Research held in Sydney, Australia, on October 17-22, 1976. The conference subject matter of particular significance includes transport of pathogens, indicator organisms for viruses, ozone disinfection, environmental hazards of Americium 241 in water, biomonitoring techniques, effects of pH on lime sludges disposed in landfills, uses of scrubber sludges for coagulation/clarification, uses of aerated equalization ponds in reclamation systems, use of magnetized resins in moving bed ion exchangers, sewage pretreatment for ocean disposal, land disposal of wastewater, corrosion protection of sewer lines, transfer of antibiotic resistance from nonpathogenic bateria to pathogens, survival of enteric viruses and coliforms in sediments around ocean outfalls, and the importance of the wastewater reuse concept. A total of 72 papers are covered.

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BY

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United States of America National Committee
for Representation of the United States to the
International Association on Water Pollution Research
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Newark, Delaware 19711

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OFFICE OF RESEARCH AND DEVELOPMENT
U. S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

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March 21, 1977

Mr. William T. Sayers, Chief
Water Quality Staff
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Washington, D. C. 20460

Dear Mr. Sayers:

This report on "Developments at the Eighth International Conference on Water Pollution Research" is submitted in accordance with provisions of EPA Grant No. R804288010 to the United States of America National Committee for Representation of the United States to the International Association on Water Pollution Research. The report contains an analysis of formal and informal developments at the Conference which are of special relevance to water pollution control activities in the United States.

Members of the U. S. A. National Committee feel confident that this report on current water research activities throughout the world will be useful to EPA's Office of Research & Development. Should questions arise concerning specific details in the report, please feel free to contact the Committee for clarification.

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October 17-22, 1977
8th International Conference on Water Pollution Research, Sydney, Australia - [illegible]

It has been a pleasure to have been associated with the Office of Research & Development in this activity. We have, in particular, appreciated the cooperation of you, Dr. Thomas A. Murphy, and Dr. Louis G. Swaby.

Sincerely,

Richard I. Dick, Chairman
For USANC Coordinating Subcommittee:

Bernard B. Berger
Richard S. Engelbrecht
Richard I. Dick
David G. Stephan

ks

Enclosure

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EXECUTIVE SUMMARY

Beginning in 1962, the International Association on Water Pollution Research has held an international conference biennially. This report is an interpretive analysis of formal and informal developments at the Eighth International Conference on Water Pollution Research held in Sydney, Australia, October 17-22, 1976, and has been prepared for the U.S. Environmental Protection Agency by the U.S.A. National Committee for Representation of the United States to the International Association on Water Pollution Research.

The Conference papers, complete with formal and informal floor discussion, will be published in the future. Because of this, this report does not contain the formal papers or the verbatim discussions. Rather, this report was prepared by the official U.S. participants in the Conference as a critical analysis of formal and informal developments at the Conference which were deemed to be of potential interest to the U.S. Environmental Protection Agency.

Important information concerning developments in international water pollution research was obtained both from the formal Conference sessions and, perhaps even more importantly, from informal information exchanged outside the formal meeting rooms. Of particular significance were the following:

--a report of possible transport of pathogens, in the form of aerosols, for considerable distances downwind from spray irrigation facilities using wastewater.

--suggestions that acid-fast organisms and yeasts may be particularly advantageous in the case of disinfection as indicator organisms for viruses.

--the finding that the presence of gas phase ozone substantially enhances disinfection as compared with ozone residual alone.

--serious concern over the potential environmental and public health hazard that may be associated with traces of Americium 241 in water.

--a report on a biomonitoring technique utilizing changes in fish respiration rates as an automatic, continuous means of detecting the presence of toxic components in wastewater.

--recognition of the reversible nature of lime stabilization of sludges as the pH of such sludges may be reduced following land fill disposal.

--a proposal that utilization of scrubber sludges in municipal wastewater coagulation/clarification may offer both economies and improved performance.

--a discussion of the advantages of aerated equalization ponds in reclamation systems leading to equalization of influent quality, improvement in ammonia stripping efficiencies, reduction in calcium carbonate supersaturation, destruction of some pathogens and facilitation of breakpoint chlorination.

--a report on use of magnetized resins in moving bed ion exchangers (including a dramatic increase in settling rate in the resin/water separation step).

--arguments presented that not even primary sedimentation is justified prior to ocean disposal of municipal sewage.

--a detailed discussion of the operation of Melbourne's Werribee Farm for land disposal of the City's wastewater.

--a description of a novel technique for corrosion protection of sewer lines using formed-in-place plastic liners.

--a startling claim of possible transfer of antibiotic resistance from nonpathogenic bacteria to pathogens.

--discussion of the extended survival of enteric viruses and coliforms in sediments around ocean outfalls with the possibility of later unpredictable resuspension and transport.

--a continuing emphasis and reemphasis on the importance of the wastewater reuse concept.

CHAPTER I

INTRODUCTION

Background

This report is an interpretive analysis of formal and informal developments at the Eighth International Conference on Water Pollution Research held in Sydney, Australia, on October 17-22, 1976. The International Association on Water Pollution Research sponsors such a conference biennially. This report was prepared for the U.S. Environmental Protection Agency by the U.S.A. National Committee for Representation of the United States to the International Association on Water Pollution Research.

The International Association on Water Pollution Research (IAWPR) is a non-governmental professional organization with the goal of advancing water pollution research worldwide to enhance the quality of the earth's water resources. It is governed by representatives of national committees of member countries. Each national committee, as a condition of membership in IAWPR, represents the water pollution research-related professions in the respective country.

The International Association on Water Pollution Research recognizes the United States of America National Committee (USANC) as the national organization representing American water pollution research interests in IAWPR. USANC is sponsored by five major professional societies with interests in water pollution research: (1) American Chemical Society; (2) American Institute of Chemical Engineers; (3) American Society of Civil Engineers; (4) Association of Environmental Engineering Professors; and (5) Water Pollution Control Federation. Each of these professional societies provides financial support to USANC for membership in IAWPR and appoints two delegates and two alternate delegates to serve on the U.S.A. National Committee.

International conferences of IAWPR have been held biennially since 1962. Conferences prior to the 1976 Sydney Conference were held in London, Tokyo, Munich, Prague, San Francisco, Jerusalem, and Paris. The 1980 Conference will be held in Stockholm and the 1982 Conference in Toronto. The Conferences represent the largest international gathering of researchers in water pollution control and, thereby, provide an invaluable mechanism for the exchange of water pollution control information by both formal and informal means. While the remote location of the 1976 Conference resulted in below-usual attendance, over 800 individuals representing over 30 nations attended.

The purpose of this report is not to present a verbatim record of the Conference. Papers complete with formal and informal floor discussion and responses from authors will, in time, be published in one of the two formal journals of IAWPR, Progress in Water Technology. Rather, the purpose of the report is to present a critical analysis of formal and informal developments at the Conference which are of potential interest to the U.S. Environmental Protection Agency. The report represents an assessment by official American participants in the Conference of the significance of developments at the Conference. Contributions of individual authors from various countries of the world are considered in the context of the reception which they received from discussers and the international audience. The analysis is not limited to formal conference developments, but includes developments from the informal exchanges between engineers and scientists from various countries which inevitably occur at such conferences.

The agenda for the Sydney Conference was developed by the Program Committee of IAWPR from papers submitted from around the world in response to invitations to submit manuscripts appropriate to any one of 26 designated topics covering the broad area of water pollution research. Reprints of papers selected for the program were available to participants in advance of the Conference, and only abbreviated summaries of the papers were presented by the authors in Sydney. Formal discussers were selected by the Program Committee prior to the Conference to prepare critical analyses of each paper. Additionally, appreciable informal discussion of the papers and of the formal discussions occurred. Appendix I contains the program for the Conference and provides additional information on the conduct of the sessions.

Report Development

This report was prepared by the official American participants in the Sydney Conference. Official participants were those individuals presenting papers, presenting prepared discussions of research work described by others, chairing or recording sessions and workshops, and/or participating in IAWPR Governing Board activities. Development of the report was coordinated by a Subcommittee of USANC consisting of the present officers (Richard I. Dick, David G. Stephan, and Richard S. Engelbrecht) together with the immediate past chairman (Bernard B. Berger).

Prior to the Conference, the USANC Coordinating Subcommittee ascertained the interest of official participants in cooperating in the development of this report and solicited expressions of interest in reviewing particular sessions at the Conference. Then, assignments for coverage of all the sessions were made as indicated in Appendix II. Appendix III contains the preliminary instructions given to participants in development of this report, and Appendix IV gives the detailed directions issued to guide the preparation of individual reports.

Reports by the individual participants are included in Chapter II. Aside from minor editing to render the reports compatible with the general format and to eliminate items unrelated to water pollution research, the reports are published here as received from the authors. The reports thus represent a critical assessment by American water pollution control researchers of those sessions of the Conference which received their special attention. The reports appear under the by-line of the reviewers and represent their personal views--not necessarily the views of the Coordinating Subcommittee or USANC.

Highlights of Chapter II as perceived by the Coordinating Subcommittee are summarized in Chapter III. Additionally, information submitted by individual participants on developments at the Conference unrelated to their sessions are summarized in Chapter III. The Executive Summary is an abbreviated version of Chapter III.

Users of the report will find the Table of Contents together with the Key to Reviews useful in locating in Chapter II the discussions of particular papers or workshops. Additionally, Appendix I should be useful in gaining a perspective on the Conference and on the contents of Chapter II.

CHAPTER II

I. SESSION

A. Theme of Session: Spray Irrigation with Wastewater

B. Papers Presented: 1. Spray Irrigation with Wastewater: The Problem of Aerosolization and Dispersion of Enteric Microorganisms.
E. Katzenelson, B. Teltch, H. I. Shuval (Israel)

II. REVIEWER

A. Name: Shaukat Farooq

B. Position and Affiliation: Assistant Professor of Environmental Engineering
Department of Civil Engineering
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III. REVIEW OF SESSION

A. Formal Paper

A.1 Paper No. 1

A paper on spray irrigation with wastewater was introduced by Dr. Shuval, who explained the problem of aerosolization of microorganisms during spraying and the possible spread of human disease by contaminated air. According to the speaker, there are some 250 communities in Israel which at present are practicing spray irrigation with wastewater and are thus being exposed to a health risk. The speaker also provided some new information concerning the epidemiological status of the communities practicing spray irrigation which was not reported in their paper. The incidence of enteric communicable diseases in 77 kubbutzins (agriculture communal settlements) practicing wastewater spray irrigation with partially treated, non-disinfected, oxidation pond effluent, is compared with 130 kibbutzins practicing no form of wastewater irrigation. The distribution of ages is reported to be the same in both the groups, although the kibbutzins utilizing the wastewater tend to have a slightly older population since this group includes a number of larger and older well-established settlements.

The data, obtained from the Department of Epidemiology of the Ministry of Health, were mainly collected for enteric diseases which could be waterborne, and include shigellosis, salmonellosis, typhoid fever and infectious hepatitis. Streptococcal infections (including scarlet fever) and tuberculosis, not considered to be associated with domestic wastewater, were selected as controls. Ratios of morbidity were determined between the settlements using wastewater effluent for irrigation and those which did not. The results indicated that disease incidence was two to four times higher in settlements utilizing domestic wastewater for spray irrigation, and ratios for shigellosis, salmonellosis, infectious hepatitis and typhoid fever were 2.2, 3.7, 2.0, and 4.3, respectively. No significant differences in disease incidence were seen for those diseases not associated with wastewater (streptococcal infections and tuberculosis). Further, no significant differences were found in disease rates for shigellosis, and infectious hepatitis during the months of winter (December-March) when irrigation is not practiced. These facts strengthen the hypothesis that there exists a relationship between irrigation with wastewater effluent and enteric disease incidence.

Finally, Dr. Shuval, after emphasizing the need for spray irrigation with wastewater effluent in Israel but noting related health effects, strongly recommended high levels of wastewater treatment, including effective bacterial and viral inactivation through disinfection, for all cases of wastewater irrigation or land disposal near residential areas, in light of the potential public health risks involved.

B, C & D. Discussions

The authors were congratulated on raising the question of health dangers due to the problem of aerosolization during spray irrigation with wastewater effluent and also for providing epidemiological data about the communities which are practicing spray irrigation. However, during the discussion several questions were raised about the study:

1. The applicability of a theoretical model to predict a density of microorganisms in the downwind direction is questioned because it does not accommodate a natural die-away rate in the atmosphere. However, improved models have been reported in the literature which do include a natural die-away rate of microorganisms and thus are closer to the real world situation.

2. It was suggested that the total plate count is a more sensitive measure of bacteria in air than the Anderson air sampler with a selective medium for certain bacteria.

3. Information was requested concerning the size and depth of oxidation ponds and the efficiency of the aerators which would help calculate the amount of water aerosolized. Unfortunately, the speaker did not have the information on hand.

4. Concerning the claim by the authors that the field of spray irrigation has been ignored, the discusser quoted that, according to a literature survey of 1975 about 131 papers on aerosolization have been published between 1907 and 1975. This indicates that the field of aerosolization has not been ignored as the authors claimed. However, Dr. Shuval rebutted this by saying that the authors meant the effects of spray irrigation on health of nearby communities, and not the spray irrigation itself.

IV. CRITIQUE OF SESSION

The authors were able to answer the question, asked quite frequently, about the relationship between the aerosolization of enteric microorganisms into the atmosphere from either wastewater treatment plants or spray irrigation and the health effects on the nearby communities Their epidemiological data are very suggestive of an increased risk of enteric communicable diseases among the utilizers of wastewater for spray irrigation. This appears to be the first time this type of information has been reported, indicating the originality of their study. At the same time, it sounds an alarm that an epidemiological study should be conducted in the United States among the people who are working at wastewater treatment plants or living close to them.

Another important part of their study was the use of indicator (marker) organisms which provided better control data. Randall and Ledbetter (1966) showed that *Klebsiellae* are the best indicators of bacterial air pollution from domestic wastewater sources. This was also confirmed by Pereira and Benjaminson (1975). However, the authors of this paper (Katzenelson *et al.*) were unable to consider this point during the selection of indicator organisms for their study. The remainder of the study simply showed that spray irrigation and surface aerators are sources of aerosolization of microorganisms.

In general, the paper was quite informative and created some good discussion; however, the discussers concentrated mainly on the experimental technicalities of the study and ignored its application.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

This research has raised a valid question about the collection of epidemiological data on the incidence of infectious disease among both sewage treatment plant personnel and residents in the immediate vicinity of the sewage treatment plants, within the United States. In 1975 Pereira and Benjaminson (1975) indicated that a combined quantitative microbiological and epidemiological study should be carried out to classify the role played by sewage treatment plants in the airborne dissemination of disease. This is a positive suggestion in light of the data presented by the authors in this study.

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I. SESSION

A. Theme of Session: Virus Removal

B. Papers Presented:

4. Virus Retention by Soil.
K. V. Abdulla Koya, Malay Chaudhuri (India)

7. The Removal of Viruses by Slow Sand Filtration.
S. F. B. Poynter, J. S. Slade (Great Britain)

10. Virus Removal in Activated Sludge Sewage Treatment.
V. C. Rao, S. B. Lakhe, S. V. Waghmare, P. Dube (India)

II. REVIEWER

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III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 4

The paper, "Virus Retention by Soil," was introduced by Dr. Engelbrecht as the authors of the paper could not attend the conference. It was shown in the study that three Indian soils, black cotton, Kanpur silt and Lateritic, were found very effective in removing bacterial virus MS2, which was selected as the model virus due to its resemblance to polio, coxsackie and echoviruses. In batch studies, it was found that the bulk of viral adsorption occurs during the first 20 minutes, then reaches a plateau within 80 to 100 minutes. Data from a continuous flow system showed the same trend as it was observed in the batch sorption test. The viral adsorptive capacity of soil depends on its clay content and the chemistry of the percolating water, e.g., pH, bivalent cations, etc. It was also observed that viruses retained in the soil column remained active following their sorption on soil.

A.2 Paper No. 10

Again the authors of the paper, "Virus Removal in Activated-Sludge Sewage Treatment," were absent; therefore, it was introduced by Dr. Malina. The objective of the study was to determine the virus removal through an activated sludge treatment plant in the tropical climate of Bombay, India. Composite samples were collected to compensate for hourly variations in viral concentration and then concentrated and assayed for enteric viruses. The authors evaluated three sampling techniques in order to establish virus removal data through the primary sedimentation tank as well as through secondary treatment. The extent of virus removal during primary settling was on the order of 41.4 to 83.4 percent, while virus removal by the activated sludge process was 90 to 99 percent under field conditions. The quantity of viruses in the final effluent in 90 percent of the cases was equal to or less than 54 plaque forming units (PFU)/ℓ.

A.3 Paper No. 7

Dr. Slade, introducing the paper "The Removal of Viruses by Slow Sand Filtration," defined the objective of the research as determining the removal of viruses through sand filters and studying different variables which affect the efficiency of virus removal. It was found that slow sand filters are extremely efficient in removing enteric viruses from contaminated waters. Factors such as low temperature, high flow rates, reduced sand depth and filter immaturity adversely affect the virus removal capacity. Another important conclusion was that viruses and bacteria behave similarly when passed through a filter; however, virus removal efficiency was better than bacteria. Further, it was found that bacterial virus T7 is an unreliable indicator of the enteric virus removing ability of slow sand filters as its removal efficiency is greater than that of enteric viruses.

B, C & D. Discussions

Discussion of the above three papers is combined as they are very much related to one another. The following comments were made:

1. It was stated that the work of Koya and Chaudhuri has provided additional evidence about the viral adsorptive capacity of the soil. The discusser then attempted to relate the virus removal capacity to the rate of filtration. Further, the discusser quoted a study by Robeck regarding the removal of viruses at different rates of filtration, i.e., Robeck observed 90 percent virus removal at the rate of filtration of natural ground water movement compared to only 10 percent virus removal when flow rate was increased to that of rapid sand filtration. In agreement with this reference, the work of Koya and Chaudhuri was able to show good adsorptive capacity of soil in the presence of clay when the rate of filtration was equivalent to the rate of ground water movement. This study suggests that conventional water treatment plants do not remove enteric viruses under all circumstances. This is a call for effective removal of viruses by other means such as disinfection.

2. Discusser commended Rao *et al.* on quantifying viruses under field conditions and considering the hourly variation in virus

concentration by collecting composite samples. He suggested that the virus removal data would have been more meaningful if the viruses were detected immediately at the time of collection. This would have demonstrated the efficiency of the concentration technique as well as that of the assaying technique.

In respect to the discussion of this paper, the discusser presented some of his data from laboratory and field studies. In lab studies, municipal sewage was seeded with polio I and then fed to a continuous flow activated sludge laboratory unit. A 2 log reduction in virus counts occurred through that process. It was found that the removal mechanism of poliovirus depends on attachment with sludge. Later, poliovirus was recovered from the sludge up to 5000 PFU/gm of dry sludge withdrawn. Furthermore, virus recovery from the sludge increased as the organic loading was increased in the system. However, a mass balance on viruses indicated that permanent inactivation of a virus occurred during association of the virus with sludge. It was observed under field conditions that at constant flow rate the removal efficiency of enteric viruses remained constant. Further, the virus removal efficiency was 90 to 95 percent in the contact stabilization process.

3. It was suggested that sandy soils do not retain viruses unless they are coated with active zooglea which is normally found in slow sand filters. Therefore the possibility exists that sandy soils with small clay content may not be suitable for virus removal in water treatment.

4. Objection was made to the selection of bacterial virus MS2 as the model virus. According to a discusser, it has been reported that bacterial virus is removed more effectively by soil than animal viruses. An adsorption study of MS2 virus and poliovirus on a membrane filter exhibited a significant difference in their adsorption behavior. According to the discusser the previous studies have been limited to poliovirus and bacterial virus while the remaining viruses have been neglected. It has been shown that reoviruses do not exhibit the same adsorption characteristics through aluminum gel as other enteric viruses do. As polio and coxsackieviruses were readily adsorbed, therefore it is expected that the behavior of reovirus in the soil will be much different than MS2.

   The discusser quoted a study showing that viruses not detected prior to rainfall were found in the ground water after heavy rainfalls in those areas where land application of wastewater is practiced. This suggested that heavy rainfalls change the environment of soil which results in leaching of adsorbed viruses by soil under different environmental conditions.

5. The efficiency of virus removal through conventional treatment processes is usually overestimated. It has been reported that

ambient concentration of enteric viruses in sewage range between 10,000-100,000 PFU/ℓ in Israel. Even after 95 percent removal through a treatment plant, residual viruses will still be quite high. This suggests the importance of disinfection of wastewater effluent prior to its utilization in irrigation.

6. Virus removal through adsorption on soil cannot be relied upon because it is a reversible phenomenon. Viruses can be leached from the particle surfaces by a change in pH or organic matter.

IV. CRITIQUE OF SESSION

The study of Koya and Chaudhuri was able to provide additional evidence that soils containing clay are very effective in removing viruses. However, the significance of the study would have increased immensely if the authors had used enteric viruses as model organisms and had studied different flow rates. An important question still to be raised is how closely the laboratory conditions duplicate the actual field conditions when studying the removal of viruses. In addition, the authors reported that viruses retained in the soil column were active but no information was given indicating whether or not the soil had an inactivation capacity. In the past, most of the virus removal studies were conducted in laboratory scale units using large virus inocula and provided information concerning the removal efficiency of the treatment process. The research conducted by Rao *et al.* was original because for the first time researchers were able to determine the virus removal efficiency in actual field conditions. Originality of the work was also indicated by the fact that the authors tried to compensate for hourly variations in the concentration of viruses by taking composite samples and to investigate various sampling techniques to establish good virus removal data through the activated sludge system.

Finally, the research of Poynter and Slade was able to answer several questions which were raised earlier concerning the first two papers. Their study was more research-oriented and provided information about the variables which could affect the virus removal efficiency through slow sand filters. This study showed that slow sand filters are very effective in removing viruses from contaminated waters and bacterial virus is an unreliable indicator for removal of enteric viruses.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

During this session it was emphasized that it is dangerous to translate the results of bacterial virus to enteric virus. In addition, even among enteric viruses there are some 100 different viruses which do not behave similarly under the same environmental conditions. Therefore, it is suggested to introduce the broad spectrum of enteric viruses in future studies rather than only bacterial virus or poliovirus. Before setting any new disinfection standards, it would be advantageous to thoroughly understand enteric viruses. Otherwise, we will be committing the same mistake as in the past when we chose coliform as a standard for wastewater effluent, which does not even provide safety against bacterial pathogens.

I. SESSION

A. Theme of Session: General

B. Papers Presented:

13. Nitrogen, Phosphate and Virus Removal from Sewage Water During Land Filtration.
J. C. Lance, C. P. Gerba (USA)

16. Faecal Coliforms and Faecal Streptococci: A Statistical Comparison using Data from England and Papua New Guinea.
R. Feachem, K. Khan, E. Rosebergen (Gr. Brit.)

19. The Effect of Ozone Bubbles on Disinfection.
S. Farooq, R. S. Engelbrecht, E. S. K. Chian (USA)

II. REVIEWER

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III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 13

J. C. Lance (USA) discussed the removal of nitrogen, phosphorus and viruses in soil columns containing a loamy sand which were intermittently flooded with secondary treatment plant effluent. The nitrogen, phosphorus and viruses were absorbed by the soil during the flooding period. Nitrification was observed during the drying period. Inability to elute any viruses from the soil with distilled water after the soil had completely dried indicated inactivation of the virus. In addition to the sorption of phosphorus to the soil, precipitation of calcium phosphate was reported to be the mechanism of phosphorus removal. A peak of nitrate in the effluent from the columns was observed shortly after flooding columns which had been flooded previously and allowed to dry. Introduction of a carbon source (dextrose) enhanced denitrification; however, nitrate peak was not eliminated.

A.2 Paper No. 16

The second paper dealing with fecal coliforms and fecal streptococci was presented by the discusser, Mr. Lane (Australia). The formal discussion and the floor discussion were more significant than the material in the paper. These comments will be presented in Section III.B and III.C rather than at this point.

A.3 Paper No. 19

The third paper, presented by Mr. Farooq (USA), discussed the effectiveness of ozone as a disinfecting agent in a clean water system consisting of phosphate buffer. The authors clearly demonstrated that the ozone residual, in fact, enhanced virus inactivation and bacterial die-off. The presence of gaseous ozone in the form of bubbles resulted in a higher degree of disinfection than ozone residual alone. The authors also proposed that *Mycobacterium fortuitum*, an acid fast organism, and *Candida parapsilosis*, a yeast found in domestic sewage, may be candidate organisms for possible indicators because of their resistance to changes in the environment as well as to ozone.

B. Prepared Discussions

B.1 Mr. Ray Rimkus presented the formal discussion of Paper No. 13 prepared by Mr. Cecil Lue-Hing of the Metropolitan Sanitary District of Chicago. He pointed out a number of discrepancies in the paper as the authors interchangeably used secondary effluent with sewage water. In fact, in the paper there are no general characteristics of the water applied to the soil columns. The possible problem with leakage of nitrogen to the ground water also was pointed out. The hypothesis of calcium phosphate precipitation in the soil column was not verified since there were no samplings of the material in the column. In fact, the measurement of the variation of pH in the column would help verify if calcium phosphate precipitation did in fact take place. Therefore, the removal of phosphates by chemical precipitation seems to be more effective and more controllable than using soil systems. It also was pointed out that the phosphorus in the effluent of 12 mg/ℓ was relatively high and was not typical of secondary effluents which would have phosphorus concentration of 1 to 2 mg/ℓ.

They also pointed out that in the Fulton County experiments with viruses in sludge, viruses only traveled 1.3 cm after distilled water was applied to the soil. However, in Fulton County the soil has a much higher clay content than the 3 percent clay reported for the soil in the Phoenix operation. The need to evaluate the soil characteristics at each specific site along with the chemical composition of the wastewater to be applied was strongly recommended.

B.2 Mr. D. J. Lane (Australia) discussed the paper on fecal coliform and fecal streptococci (Paper No. 16) and questioned whether the experimental work reported in the paper was in fact designed as a statistical exercise rather than interest in fecal coliform and fecal streptococci as indicator organisms. The variations may be inherent to any lab analyses and statistically the fecal streptococci seem more appropriate, especially from a taxonomic and physicological point of view. However, Mr. Lane did question the sanitary significance of fecal streptococci and presented some data from South Australian streams. At normal flow, *E. coli* and fecal streptococci were presented in the same numbers. However, during high flow periods the *E. coli* are much greater in number than the fecal streptococci. During low flow periods no trend was obvious. In unpopulated areas; therefore, the *E. coli* were the more significant indicators. He also pointed out that the fecal streptococci data should be used to substantiate the *E. coli* data.

B.3 Dr. W. Stumm (Switzerland) discussed ozone disinfection (Paper No. 19). He stressed the need to understand the speciation of ozone before investigating disinfection, much like it was necessary to understand the various species of chlorine before investigating disinfection. The understanding of the speciation of ozone is very limited. Ozone is very reactive and will react with hydroxyl (OH^-) ion or other materials to form hydroxide radicals which will carry on other reactions with the substrate. He stressed the effects of pH, organics in the water, and other chemical constituents on the species of ozone which would be present. The phosphate buffer system used by the authors was different than the carbonate buffer systems in which bicarbonate acts as a scavenger of the OH radical and stabilizes the ozone. However ozone residuals were much more important than the hydroxide radicals in disinfection.

The bubbles of ozone on disinfection were not significant. Dr. Stumm pointed out that the ozone bubbles may cause flotation and carry the bacteria to the surface of the liquid at which point the bacteria are transferred to the gas phase when the bubbles burst. The detention time in treating wastewater with minimum ozone residuals is significant since the wastewaters have an oxygen demand and, therefore, an ozone demand. The significance of the bubble size cannot be determined from a laboratory system which is 50 cm tall since most of the installations in the field are 2 to 3 meters deep. However, Dr. Stumm did commend the authors for their diligent effort in looking at a continuous flow system. He felt additional work had to be conducted before a more complete understanding of the use of ozone as a disinfectant could be applied more universally.

C. Floor Discussions

C.1 A number of significant factors were brought out in the discussion of the use of soil systems for removal of nutrients and viruses. The possibility of removing the phosphorus by pretreatment with lime precipitation and disinfection of the effluent to eliminate viruses and pathogens was suggested along with the high pressure spray to prevent soil plugging with suspended solids. Dr. Lance indicated that the use of lime would prevent clogging. However, the need for pretreatment was dependent on the quality of the effluent applied to the land. He pointed out that the wetting and drying of the soil prevented clogging, although clogging was more prevalent when using the effluent from an activated sludge plant containing 10 mg/ℓ of suspended solids compared to the application of primary sewage containing several hundred mg/ℓ of suspended solids. Apparently the primary sewage solids are more easily degraded and allow for high application rates.

A question was raised regarding the length of time and rate at which wastewaters could be applied to vegetated areas before the grass would die. Dr. Lance pointed out that the use of flood tolerant grasses would be more acceptable than the Bermuda grass which was used in the vegetated column experiments. The tremendous differences between different soil systems were also pointed out. Some contain heavier clays which would provide for more adsorption of viruses while others contained very little clay. It was also pointed out that it is extremely difficult to predict and extrapolate data from one site to another and that it is essential that the characteristics of the soil at specific sites be carefully characterized and constituents identified. Possibly in the future, a sufficient data bank of information would be available regarding various soils to at least provide a starting point in looking at the applicability of various soils to water reclamation systems. Dr. Lance indicated that the soil in the Phoenix area contained only 3 percent clay and that with heavier clays you find less movement of viruses. Mr. Rimkus made a similar point.

Dr. Lance felt that the movement of nitrates into the ground water would lead to a contaminated situation and suggested that pumping the reclaimed water with a portion of the ground water would minimize nitrate buildup in the ground water. Dr. Lance also pointed out that he had no direct evidence of phosphate precipitation, although removals of 6 to 8 mg/ℓ were observed and that the calcium content in the effluent from the columns was greater than the effluent. The effectiveness of the soil system in removing phosphorus after all the calcium was flushed from the system was questioned.

C.2 Dr. Shuval (Israel) led off the floor discussion on fecal coliform and fecal streptococci by pointing out that the significance of the organisms from a public health point of view instead of as a statistical convenience should be the prime consideration. He pointed out that *E. coli*, fecal coli and fecal streptococci in raw sewage are relatively constant in number. However, the fecal streptococci have more resistance and, therefore, will survive longer in the environment and the die-off is less rapid than that observed for *E. coli* and fecal coli. Therefore, he questioned the efficiency of coliforms as indicators of pathogens and proposed that fecal streptococci behave more similarly to viruses in the environment. The survival of salmonella, *E. coli* and viruses in marine environment were reported. The T_{90} was 45 minutes for *E. coli* and many salmonella strains. However, other strains of salmonella were more resistant to changes in the environment. On the other hand, the T_{90} for enteroviruses was 24 hours.

The question was raised by Rao of India whether there should be more parallelism between the indicator organisms and pathogens. The organisms should indicate the presence of pathogens, and the analysis of water to indicate the possible presence of fecal pollution did not necessarily indicate the presence of pathogens. The relative significance of coliform and fecal streptococci was pointed out. In ground water near Nagpur, India, fecal streptococci were detected but no coliform organisms were observed. Animal feces contained a much higher concentration of fecal streptococci than fecal coliform. Therefore, the fecal streptococci indicate animal pollution. Fecal streptococci, which survive longer than the fecal coliform, would be more indicative of pathogens.

C.3 The criteria for an indicator organism were reiterated during the discussion, namely that the organism is more resistant than pathogens, although not a pathogen itself, and is easily analyzed and ubiquitous. Other organisms have also been proposed as indicators in the formal paper presented by Mr. Farooq. Using a combination of coliform and fecal streptococci would be more useful in identifying the source of fecal pollution. Bruce Hanes (USA) felt that the main point of the paper, namely the study of the statistical variations of the present test being used, was not understood by the audience. We must understand the significance of the variation and the analytical procedures before we can fully utilize any indicator organism in assessing pollution.

Coliform has been used in conjunction with fecal streptococci for a long time in France. This work must be continued in order to develop the relative significance of these organisms as indicators of the presence of pathogens. However, the blind application and the usefulness of the ratio of fecal streptococci to coliform is questionable.

Dr. Chian (USA) directed comments to Dr. Stumm's discussion and agreed that the mechanism of ozone disinfection must be approached in a similar fashion as the work on chlorine disinfection. However, he felt that first indications are that the ozone, in fact, enters the cell and acts intracellularly. Therefore, the transfer of ozone into the cell affects disinfection and the higher the concentration of ozone in the bulk liquid, the higher the transfer of ozone into the cell. The question of temperature effects on disinfection was also raised. Mr. Farooq indicated that as the temperature increases the ozone concentration in the bulk liquid is reduced, and therefore the disinfection rate is reduced.

Dr. Wachs (Israel) pointed out that in studies in which he was involved, quasi-residual persisted in water even though a residual ozone was not measured, and disinfection continued with seeded bacteria in the system. Dr. Stumm pointed out that the rate of reaction is based on many factors. Dissolved ozone is, in fact, a disinfectant and the residual ozone is a function of the organic concentration in liquid, the bicarbonates and the OH^- decomposition. The radicals formed during ozonation may be involved in the quasi-residual mentioned by Dr. Wachs.

IV. CRITIQUE OF THE SESSION

The material presented in the three papers in this session was quite diverse. The use of soil systems to reclaim water in arid or semi-arid areas is quite acceptable throughout the world. Heavy metals in the applied wastewater are potential problems. The efficiency of phosphorus removal in soils systems was questioned, and the concensus seemed to be that removal of phosphorus by chemical precipitation is more effective. Complete nitrogen removal also is not possible with the soil system. Therefore, there are some risks involved in reclaiming water from a soil infiltration system. However, the retention of viruses in the soil is significant. Extrapolation of data from one soil system to another can be extremely hazardous and should be avoided.

The use of the coliform organism as an indicator seems to be universally accepted. However, it is apparent that the use of a more resistant bacterium, such as fecal streptococcus in conjunction with the coliform analysis, can provide more useful or meaningful information. However, the total absence of an indicator organism does not guarantee that viruses are not present in the water. Although the use of an acid-fast organism and a yeast was proposed, there was no uniform acceptance of these organisms as replacements for fecal coliform or fecal straptococci.

The effectiveness of ozone as a disinfectant in a clean water system consisting of a phosphate buffer was demonstrated. However, the chemical reactions of ozone in waters which contain organic material and other reacting material is far from being completely understood. An ozone residual or quasi-residual is responsible for bacterial disinfection, although speciation of the ozone in clean water systems will aid in developing the fundamental understanding of ozone as a disinfectant. The work must be expanded to evaluate the effectiveness of ozone as a disinfectant by using wastewater treatment plant effluents which contain organic material and other substances which will exert an oxygen demand and therefore an ozone demand. A major advantage of ozone is the fact that, at the present time, there is no product of ozonation other than the quasi-residual which persists in a similar fashion as do chlorinated organics. Therefore, ozonation of secondary effluent may provide a step in the right direction in eliminating potential toxic or possible carcinogenic materials in natural water which may eventually be a source of water supply to other communities.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Soil systems and land have been used for the reclamation of wastewater as well as for the disposal of wastewater ranging from raw sewage to effluents from biological treatment facilities. A variety of papers dealing with different aspects of wastewater disposal or reclamation using land systems were presented at the conference. Detailed reports are being prepared by other individuals; however, it is necessary to draw on some of this information in identifying significant and future research needs. The application of wastewater with or without treatment to the land must be reviewed in the context of the overall objective of the system, mainly wastewater disposal, reuse of water for irrigation of edible crops or animal fodder, or infiltration for reclamation of water. In all cases the characteristics of the soil system must be defined, and the capacity of the soil system established. Specifically, additional information is required in the following areas:

1. The significance of the clay fraction in the soil and the absorption and retention of nutrient and cations, especially heavy metals

2. Identification of the reactions which take place in the soil, in particular those resulting in the removal or transformation of nitrogen and phosphorus

3. The exchange capacity of the soil and the leaching of cations from soil, as well as tolerance of the soil and vegetation to various cations and salts in general

4. The introduction of additives to the soil to enhance infiltration rates as well as specific reactions for the removal of pollutants

5. Characterization of the soil with regard to the acceptable application rates of liquids and the capability of these soils to retain pollutants

6. The pretreatment requirements dictated by the capacity of the soil prior to application and other factors which affect bacterial die-off and virus inactivation, specifically the composition of the soil and the ability to retain viruses and bacteria

7. The significance of desiccation of the soil system on virus inactivation and bacterial die-off

8. The effects on pathogens of exposure to sunlight of wastewater during application for infiltration or irrigation

The shortcomings of using *E. coli* as an indicator organism in natural waters have been identified. Specific questions which must be answered include:

1. Would the use of fecal streptococci or fecal coliform be more representative of the presence of pathogens in water systems in the United States than in other parts of the world?

2. Should an indicator organism also be responsive to changes in the environment in the same way as enteroviruses?

3. What is the statistical validity of analyses for fecal streptococci and possibly enteroviruses?

The use of acid-fast organisms or yeast as indicators of the quality of water does not seem very practical although these organisms may be more representative of the response of enteroviruses to environmental changes. If viruses are the main target of indicator organisms, it seems that a system can be developed whereby field personnel can concentrate the viruses in water samples and store these samples under refrigeration for subsequent analysis in a central laboratory equipped for assaying samples for viruses.

The question of indicator organisms in the United States is somewhat a moot point since the number of indicator organisms, pathogens and viruses is markedly reduced during biological treatment of municipal wastewater. If the 1977 guidelines of the PL 92-500 are to be met, municipal and industrial effluents will have secondary treatment before discharge into the navigable waters. The benefit of indicator organisms would be in identifying non-point sources of pollution. The transmission of diseases through the water route is also addressed in the safe drinking water legislation. Adequate treatment of water supplies, including disinfection, should continue to reduce the transmission of diseases via the water supply system.

Ozonation for the disinfection of secondary effluents from municipalities should be evaluated in light of the fact that disinfection with chlorine results in the formation of chloramines and chloro-organic compounds which may have toxic effects on aquatic organisms and potential carcinogenic effects on humans. The compounds which provide the quasi-residual effect in ozonated water should be identified to establish any long lasting residual effects on the aquatic system.

Understanding of the mechanism of disinfection with ozone is of significance if ozone is used for the disinfection of drinking water supplies. In this connection the speciation is important in order to optimize the process. However, in the case of disinfecting biologically treated municipal wastewater, the ozone demand exerted by the residual organic compounds and other chemical constituents of the wastewater is significant. Other factors, such as contact time and required dosage as well as temperature effects, should be established in order to develop proper guidelines for design and operation of ozone systems for disinfecting biologically treated wastewaters.

I. SESSION

A. Theme of Session: Lakes and Reservoirs Water Quality

B. Papers Presented: 2. Great Lakes Water Quality Agreement.
J. P. Bruce, P. M. Higgins (Canada)

5. Localised Destratification of Large Reservoirs to Control Discharge Temperatures.
F. L. Burns (Australia)

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III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 2

A paper describing activities under the auspices of the International Joint Commission established in 1972 by an agreement between the USA and Canada and summarizing Canadian participation was presented. The paper is very descriptive, dealing basically with the organization of IJC, ongoing projects and goals. The paper itself does not present information not already known to U.S. participants in IJC related projects.

A.2 Paper No. 5

The paper describes an investigation involving hydraulic model studies to develop a destratification installation for a large reservoir in Victoria, Australia. Australian limnologists, unlike those in the U.S., are concerned with cold temperatures downstream from reservoirs as a result of releasing cold hypolimnic waters. Many species of native fish require warm water in spring or early summer for breeding. The options investigated by the River Murray Commission included construction of a model with multi-level outlets equipped with an aeration device and high energy water jets located in the vicinity of the outlet, to produce localized destratification and, thus, provide control over discharge temperatures.

The model test results indicated that the most effective destratification arrangement was a combination of a water jet and an aeration curtain. The water jet alone tended to dissipate its effect over a wide area, the currents spreading quickly along the thermocline. The introduction of an aeration screen, bubbling air up from the bottom across the path of these jet induced currents, tended to throw the jet current back onto itself and produce concentrated mixing in depth. Aeration alone tended to produce mixing mainly above the thermocline. The authors did not provide information or energy requirements for such a system.

B. Prepared Discussions

B.1 A prepared discussion of Paper No. 2 was presented by K. W. Lewis (Australia) who was also chairman of the session. His discussion focused on several questions related to the Australian view on the program. It was evident from the formal paper that much of the phosphorus reduction from the point sources has been already achieved. But phosphorus from non-point sources is sufficient to sustain eutrophication. A question arises whether nitrogen removal will be required.

Another question or comment was directed to enforcement of pollution control measures. The government of Australia usually considers the economic status of a region before enforcing strong pollution control measures. Among the factors of interest are level of unemployment, development needs, etc. The discusser also inquired as to the number of people working on the program and size of the IJC staff.

Mr. Higgins pointed out that IJC is facing an overwhelming task. There are 29 permanent employees but IJC also relies on external committees, and on research programs being conducted by various research institutions. A substantial number of man-hours is devoted to IJC tasks by U.S. and Canadian nationals who are not part of the IJC staff.

The nitrogen reduction problem will be solved in the future. It is known that phosphorus was stimulating eutrophication in Lake Erie and Lake Ontario, and it is realized that land drainage is a significant source of phosphorus.

Industrial and government enforcement experience (in Canada - comment by the reviewer) is not different from Australia. The Canadian paper industry has been given 10 to 15 years to cleanse their wastewater effluents.

B.2 The formal discusser of Paper No. 5 (L. H. James, South Africa) pointed out that the destratification system design employing water jets could lead to uneconomic energy consuming solutions, particularly when high energy water jets are used. It appears that an aeration only system would achieve the same result at considerably less operating cost than the water jet and aeration solutions proposed in the paper. Energy requirements for the destratification system proposed in the paper were estimated by the discusser as follows:

Air only	92 kw
Air plus water jets	511 kw

Inefficiency of the Australian system is due to the use of high kinetic energy water jets. Economy could have been improved if large volume low velocity water jets had been used. Until 1976 localized destratification had not been attempted in South Africa. Consideration is now being given to a localized destratification installation to intercept a high density current caused by a highly mineralized tributary to a major water supply reservoir for Johannesburg, South Africa.

In response to the formal discusser's comments, the author provided some indicators on economics of the system. It has been estimated that a multiple-level outlet would cost A$1.5 mil while the proposed localized destratification would cost about A$360,000 (capital and operation cost based on 6 months operation). He also pointed out that the proposed system is experimental only.

C. Floor Discussion

C.1 Seven discussers participated in the floor discussion of Paper No. 2. About half of the contributions were seeking clarification, e.g., how was the agreement reached, what are the expenditures, what is the effect of the economy on the IJC activities (Mr. Kennedy-Good from New Zealand), in how many cases was the targeted phosphorus concentration of 1 mg/ℓ in sewage effluents met (Mr. Zielstra from the Netherlands). These questions were satisfactorily answered by the speaker.

Two discussers questioned the statement that phosphorus is the limiting nutrient accepted by IJC for the Great Lakes. Mr. Kinspord from New Zealand noted that once the lake becomes eutrophied, natural sources of phosphorus and phosphorus recycle can sustain eutrophication and in this case nitrogen becomes the limiting nutrient. Most of the phosphorus loading is associated with sediment and practically independent of the wastewater input. In response, Mr. Higgins stated that phosphorus was stimulating eutrophication in Lakes Erie and Ontario but it has been realized that land drainage is a more significant source of phosphorus than waste effluents. There is no question that nitrogen control will be considered in the future. Mr. Novotny (USA) pointed out that some of the significant pollutants (phosphorus, ammonia, heavy metals, pesticides) can be readily adsorbed by sediments. A large portion of sediments is deposited in estuary and harbor areas of the Great Lakes tributaries and may never reach the lakes. Thus, the loading of these pollutants carried by the tributaries may not be the same as the loading to the lakes.

In replying, Mr. Higgins said that he recognized the problem, and he stated that the role of estuary and harbor areas as a sink for pollutants will be addressed to a greater extent in the future. Mr. Ellis (Canada) questioned the concept of "mixing zones" where the IJC quality objectives are not expected to apply. He stated that such a concept is controversial since it brings receiving waters into the treatment process. In replying, the speaker stated that the new IJC recommendations do not propose abandoning water quality objectives in the mixing zones.

C.2 In the floor discussion of Paper No. 5, Mr. Sommerville (Australia) noted that no target discharge temperature was specified. The author answered that biologists were unable to provide any specific answer as to the minimum downstream temperature. Mr. McPhee (Tasmania-Australia) pointed out that the only danger he saw in discharging colder hypolimnic water was increase in corrosion. Large sums are involved in the destratification systems. How were the benefits evaluated - the answer was that the benefits are synonymous with satisfying conservation interests downstream from the reservoir.

The Australian discussers reported on reservoir stratification in their area of interest. In Queensland all reservoirs have low land tributaries and the thermocline can be found about 2 m below the surface. In the sydney area, the thermocline is at a depth of 6 m.

In concluding the discussion the speaker pointed out that local destratification needs about one half the energy input as compared to full destratification. However, once a small reservoir is fully destratified it stays destratified while local destratification will return to stratification overnight.

D. Other Observations and Comments

Further details on the project can be obtained from State Rivers and Water Supply Commission of Victoria, River Murray Commission or Hydraulic Experimental Station, Werribee, Australia.

IV. CRITIQUE OF SESSION

The first paper was very well received. The paper provides good information on the organizational structure and activities of the International Joint Commission. The major discussion topics in and out of the lecture hall included experience with large scope international cooperation, effect of economy on policy for enforcing pollution control measures and problems of eutrophication. The discussion somehow questioned the strong emphasis on phosphorus removal only and participants expressed their experience as to the limiting nutrients for eutrophication control. As stated in a previous section, some experts from Australia and New Zealand were more in favor of nitrogen control rather than phosphorus control.

The effect of economics on national policy for pollution control in the USA and Canada on one side and Australia and New Zealand on the other side also substantially differs. The Australian government does not strongly enforce pollution control measures in areas with such problems as high unemployment.

The second paper seemed more controversial since it represented a report on an initial phase of the research. Failure to evaluate the economics of the proposed system was criticized by the formal discusser.

From the discussion it seems that localized destratification can be achieved cheaply by aeration only at an expenditure amounting to about 20 percent of the proposed system.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Two problems emerged in the discussion of the first paper, first the problem of nitrogen control in waste effluent to the Great Lakes, and second, the problem of pollutants adsorbed on sediments and estimation of what fraction of sediment adsorbed pollutants will reach the lakes and what fraction will be deposited in estuaries and harbor areas. The paper itself reports on pollution control activities in Canada and the U.S. and as such it does not represent a contribution to U.S. water pollution problems.

From the discussion of the latter paper it was evident that the research did not reach its final stage. However, there is one point the U.S. water pollution research programs should find interesting - Australians do not accept the notion of cold water streams downstream from a reservoir. They want to maintain the original warm water fish and biota population. Thus, their emphasis is on warming reservoir releases rather than supplying high amounts of oxygen to limited downstream reaches which are to be used for trout fishing. The costs and benefits of the two approaches should be evaluated for U.S. conditions.

I. SESSION

A. Theme of Session: Surface Water Quality

B. Papers Presented: 8. A Multidimensional Analysis of the Results of the French 1971 Surface Water Quality Network Control in the River Basin "Seine-Normandie"
Y. LeFoll, R. Pinoit, A. Lescuer (France)

11. Hydrodynamics of Bubble Plumes and Oxygen Absorption in Stratified Impoundments.
F. Rayyan (Saudi Arabia), R. E. Speece (USA)

II. REVIEWER

A. Name: Vladimir Novotny

B. Position and Affiliation: Assistant Professor, Department of Civil Engineering
Marquette University
Milwaukee, Wisconsin 53233

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 8

A new method of statistical analysis of water quality surveillance data was presented in the paper. The data information matrix for the basin Seine-Normandie in France for the year 1971 represented 1800 samples with a total of 50,000 water quality parameter values. The analysis was based on classification of all samples to get a limited number of categories according to the concentration levels of the measured parameters. The method which was used was a multidimensional statistical technique called "correspondence factorial analysis." It positions a sample in a space which has as many dimensions as the total number of available parameters. By looking at the shape of the volume thus created, it is possible to identify the parameters, the variation of which plays the most important role in describing the various aspects of pollution. By this method it is also possible to regroup all the samples which are close together in this multidimensional space and by that different water types can be defined.

The volume created by the sample results placed in the multidimensional space is projected on a limited number of plane sections, determined in such a way that they represent as much as possible the main characteristics of the shape of the volume. These plane sections are determined by the inertia axes of the volume. The F_1 axis is usually a water quality axis represented by such parameters as BOD_5, COD, NH_4^+ and DO. The F_2 axis is mainly affected by flow. In order to use the statistical technique for water quality evaluations, the multidimensional space is divided into segments according to various water quality classes. The classes are based on French water quality criteria which divide water quality into five quality grades (see Fig. 8 in the original paper and in Fig. 1 attached). Adding hardness and salinity of water and including low flow-high flow quality separation, 13 water quality groups were identified in the Seine-Normandie basin and graphically plotted on water quality maps.

A.2 Paper No. 11

The paper introduces a modified computer mathematical model describing hydrodynamic behavior of bubble plumes within stratified reservoirs. The model was calibrated initially using a controlled laboratory system. The actual plume diameter and centerline velocity plots versus elevation were correlated with the computed values provided by the model. The observed and predicted stopping points of the plume were also correlated. The model was then correlated with field data from bubble plume generated in a 30 m (95 ft) stratified lake. The observed and predicted results agreed within 10 percent. This agreement was considered by the authors as satisfactory and, subsequently, they used the model to design a full-scale hypolimnium oxygenation system for Clark Hill reservoir near Augusta, Georgia.

Since the authors ruled out the use of air for destratification due to anticipated danger of nitrogen supersaturation, commercial oxygen was used instead. The oxygen plume can be designed to provide 90 percent absorption of oxygen by water without destroying the stratified conditions which provide the cold temperatures required downstream for trout.

The author in his presentation stated that in the USA there were almost 100 impoundments with hypolimnium DO concentrations of 0-1 mg/ℓ. The downstream reaches which are supplied by the oxygen lacking hypolimnic water are usually designed as trout streams. The effectiveness of tailrace aeration seems to be very low (only up to 1 mg/ℓ) and very expensive.

B. Prepared Discussions

B.1 Formal discussion of Paper No. 8 was by J. J. Wright (Australia). His discussion was focused on various clarifying questions. The questions touched the problem of site sampling, site selections which seemed to be based on a trial-and-error basis rather than on an optimal solution. Another problem raised by the discusser was separating seasonal and geographical water quality effects. The cost of such monitoring programs is also of interest. The increase of pollution with flow should be also explained. The paper itself does not provide enough information to permit an understanding of the method of data evaluation, the statistics involved, and the relationship of water quality to water uses. In answering the discussers questions, Mr. Lesouef stated that the cost of the monitoring program for the year 1976 was F 8 mil (5 F = $1) and the cost of evaluation of the results was F 0.4 mil. French water quality grades are related to water uses, e.g., grade 1A represents water usable for water supply. The method can be used for separating point and non-point sources (except for nitrates). Site to site variations are more important than seasonal variations. The results of the 1971-1973 programs were used to amend the 1976 program. In the 1976 program the frequency of data acquisition was reduced according to the variability of the parameter in the previous years and degree of correlation between the parameters.

In conclusion Mr. Lesouef stated the present French water pollution control policy:

1. Keep rivers clean that are already clean.

2. Reduce pollution and keep it reduced.

B.2 The formal discussion of Paper No. 11 was presented by P. A. Krenkel from USA. In his discussion Dr. Krenkel criticized several points of the paper:

1. It should be understood that presence of cold water does not automatically mean the classification of the stream as trout reach.

2. Nitrogen supersaturation is unlikely to occur.

3. Size of bubbles varies but this factor was not included in the model.

4. Transfer rate is proportional to the diameter of bubbles.

5. Increase of bubble size during its rise should be anticipated.

6. Pressure will have effect on oxygen saturation value.

7. Effect of surfactants can be quite significant.

8. Experimental data are very sparse; many times only one point is used for comparison of the model or the measured data.

In answering, Dr. Speece stated that nitrogen supersaturation is very difficult to measure. First mortality due to the supersaturation of water by nitrogen was noticed on the Columbia River. Size distribution of bubbles was approximately 1 mm. Coalescence of bubbles was not included; however some coalescence was observed in the laboratory. Nitrogen is stripped from water by pure oxygen into the bubbles, but due to the high hydrostatic pressure stripping is retarded and very low. Effect of surfactants was not included and was considered negligible.

C. Floor Discussions

C.1 The vagueness of the method proposed in the paper was one of the problems. Only few questions were raised and they related to the following:

1. Difficulty in understanding the method and interpreting the figures.
2. Relation between the model and evaluation of water quality.
3. Seasonal effects, time effects and daily fluctuations.
4. Distinguishing between point and non-point sources and identification of sources of pollution.

In responding, the author stated that the method is still being developed and improved. It provides a good tool for evaluating large water quality data matrices.

C.2 Mr. Berns from Australia asked about the economic value of trout fishing downstream from the reservoir. Dr. Speece pointed out that the question is not one of economics but a political matter imposed by Congress. Mr. Jones (Australia) asked about the effect of oxygenation on the concentration of heavy metals which have a tendency to go into solution if oxygen is added. Dr. Speece replied that the authors did not look into this problem. It was his opinion that since the DO level usually does not go down to 0 mg/ℓ, the transformation of $SO_4^{=}$ to $S^{=}$ does not take place, a condition necessary for precipitation or dissolving metals.

A question was raised as to the availability of diffusers and problems associated with installation and operation. The question was answered both by Dr. Speece and Dr. Krenkel. Dr. Krenkel related the use of aeration and oxygenation equipment to energy resources. In the present enery crisis the process seems to be uneconomical. Dr. Speece compared use of pure oxygen with diffused air systems and surface aerators. Surface aerators are extremely costly. Pure commercial oxygen seems to be more efficient than diffused aeration.

D. Other Observations and Comments

Since the explanation of the statistical method used by the French scientists to evaluate water quality data was not quite clear, Mr. Lesouef was contacted during the conference and provided a more detailed explanation. The method evaluates water quality data in a multidimensional space. Each dimension represents a water quality parameter. A three dimensional case is shown on Figure 1. Each water quality sample represents a point in this multidimensional space. The volume occupied by the points is then transformed and plotted with its axes of inertia as coordinates. This transformation then enables the subsequent evaluation.

The method is described in several French scientific reports, e.g., Benzecri, J. P., "La 'analyse des données," or Diday, M., "La methode des nuees dynamiques."

IV. CRITIQUE OF SESSION

The first paper described a new quite original method of evaluating large water quality data matrices. The paper, however, was not clear as to the description of the method and data matrix transformation into the two-dimensional linear graph. However, the paper was well received by the formal discusser and session participants. Many scientists from different nations inquired as to the availability of a better description of the method used in the paper.

The second paper had the usual handicap of papers dealing with mathematical models, i.e., many equations; therefore, only very few people were able to comprehend the presented material. Several shortcomings were pointed out by the formal discusser who stated that insufficient experimental data (especially controlled laboratory data) were presented to document the validity of the model.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

As was stated earlier the first paper introduces a relatively new statistical technique applicable to large water quality data matrices. Although more information from French authors and from the Seine-Normandie basin staff is necessary, its applicability should be tested in the U.S. With few exceptions such as ORSANC, Delaware River system, and some others, a comprehensive water quality surveillance program is relatively new to this nation and few scientific methods exist for evaluation of the data. The French method is not simple statistics, but rather a sophisticated statistical transformation model and it seems very promising.

The second paper was developed in the USA and reports on research activity which has been conducted in this country for years. Plume rise models have been developed at other research institutions in this country, such as MIT, California Institute of Technology, Tennessee Valley Authority, Vanderbilt University and others. It is very difficult to ascertain which model is the best and under which conditions.

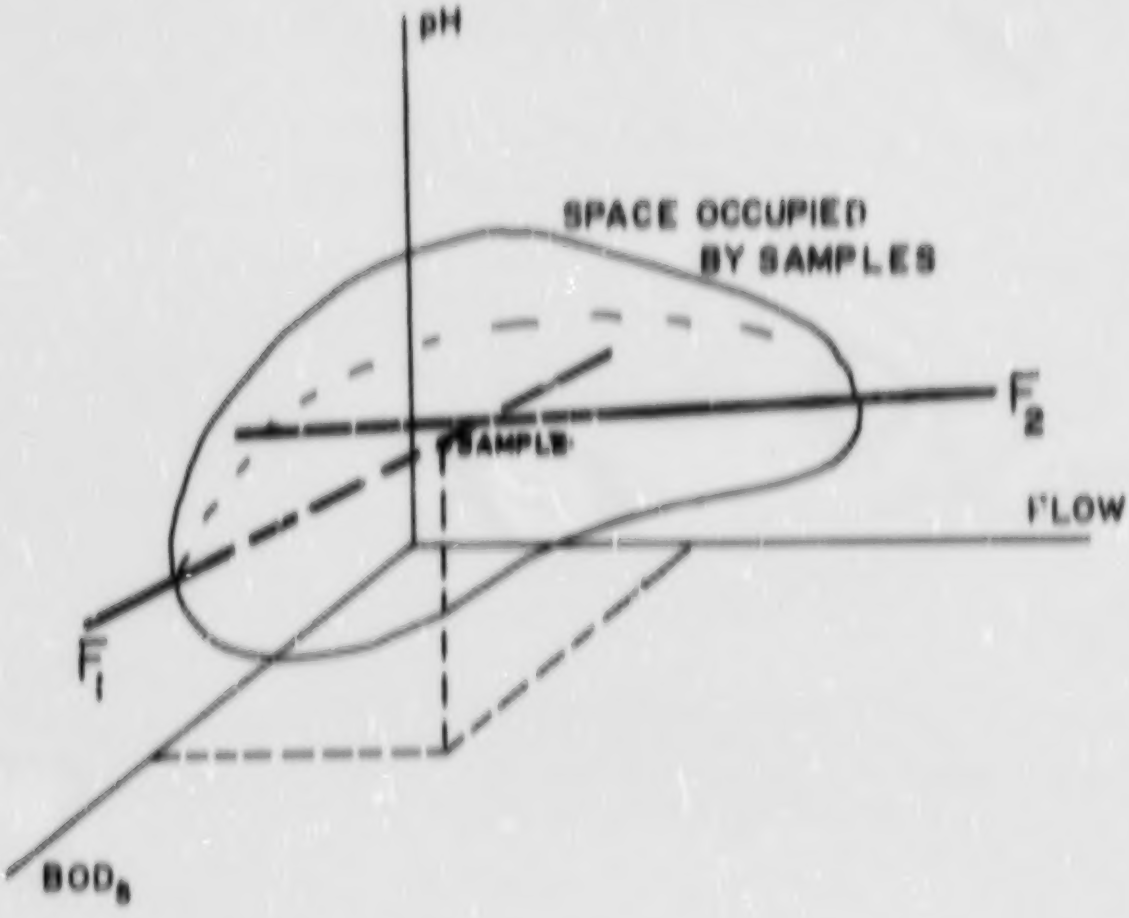

FIG. I WAT. QUALITY DATA TRANSFORMATION

Water Quality Standards

Qualité	1A	1B	2	3	4
(1) Temp. eau	<20	20-22	22-25	25-30	>30
(1) pH	6,5-8,5	6,5-8,5	6,5-8,5	5,5-9,5	<5,5 ou >9.0
(1) O2 dissous mg/ℓ	>7	5-7	3-5	<3	
(1) Ind. de satur. %	>90	70-90	50-70	<50	
(1) DBO5 mg/ℓ	<3	3-5	5-10	10-25	>25
(1) DCO "	<20	20-25	25-40	40-80	>80
(2) SO4 "	<250			>250	
(1) NH4 "	<0,1	0,1-0,5	0,5-2	2-8	>8
(1) NO3 "	<44			44-100	>100
(1) Phenols "	<0,001		0,001-0,05	0,05-0,5	>0,5
(2) Orthophos. "	<0,4	0,4-0,7	>0,7		
(2) Deterg. Anion "	<0,2		0,2-0,5	>0,5	
(2) CN "	<0,05			>0,05	
(2) Cr "	<0,05			>0,05	
(2) F "	<0,7	0,7-1,7		>1,7	
(2) Pb "	<0,05			>0,05	
(2) Se "	<0,01			>0,01	
(2) Cu "	<0,05		0,05-1	>1	
(2) Zn "	<3	3-5		>5	
(2) As "	<0,05		0,05-0,1	>0,1	
(1) Fe "	<0,5	0,5-1	1-1,5	>1,5	
(1) Mn "	<0,1	0,1-0,25	0,25-0,5	>0,5	
(2) Cd "	<0,005			>0,005	
(1) Subs. Extrac. "	<0,2	0,2-0,5	0,5-1	>1	
(1) E. coli N/100 mℓ	<2000		>2000		
(2) Streptoc. " "	<20	20-1000	1000-10000	>10000	
(1) I. Lentique	>9	7-8	5-6	3-4	<2
(1) I. Lotique	>9	7-8	5-6	3-4	<2
Salinité	0	1	2	3	4
(1) Conductivité	<400	400-750	750-1500	1500-3000	>3000
(1) Cl	<100	100-200	200-400	400-1000	>1000

Fig. 8

I. SESSION

A. Theme of Session: Groundwater Pollution

B. Papers Presented:

14. Technical Requirements and Analysis Methods for Evaluating the Environmental Consequences of Groundwater Contamination.
R. W. Nelson (USA)

17. Pilot Plant Investigation of the Evolution of Various Pollutants During Artificial Recharge of an Aquifer by a Basin.
M. Rizet, J. Malleviale, J-C. Cournarie (France)

20. Hydrochemical Effects of Waste Percolation on Groundwater in Basalt near Footscray, Victoria, Australia.
M. Rina (Australia)

II. REVIEWER

A. Name: T. E. Larson

B. Position and Affiliation: Head, Chemistry Section
Illinois State Water Survey
Urbana, Illinois 61801

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 14

This is a rather thorough scholarly evaluation of technical requirements for analysis of environmental consequences, by way of developing location-arrival time and location-quantity distributions. In an example the flow system kinematics provide the geometry of flow in the subsurface flow. The paths of flow are needed for individual particles moving through the flow system to the points of emergence at the outflow boundaries. The paths of flow and the arrival time at outflow boundaries are determined by the path lines. The differential equations for the path lines are referenced by the author to his publications submitted for publication to Water Resources Research, January 1975. (As of the August 1976 issue, these referenced papers have not been published.)

One gets the feeling that the author glosses over the difficulty with transport analysis. Bredehoeft and Pinder (Water Resources Research [1973] p. 194 -- not referenced) do a better job. Little is said about chemical reactions in transport.

The author did not appear and there was no discussion

A. 2 Paper No. 17

A pilot plant was used for artificial recharge to investigate the evolution of various pollutants in the basin and subsequent ground layers. The following compounds were introduced separately:

1 mg/ℓ Pb NO$_3$

1 mg/ℓ Na alkyl aryl sulfonate

2 mg/ℓ a synthetic alcohol (nonionic)

2.5 mg/ℓ phenol

12.5 mg/ℓ hydrocarbons and surfactants (soluble oil)

300 mg/ℓ refinery effluent

1 μg/ℓ lindane

10 μg/ℓ lindane

Algal and bacterial counts were made in the basin water and in the sand before and after passage of the flows. The sequence of flow after the basin was 10 cm washed sand, 2.8 m raw sand, 10 cm gravel, 2 m ground chalk and 2 m large pieces crushed chalk.

The lead never penetrated to the raw sand, and precipitated largely in the basin above the washed sand due to the high alkalinity (level never mentioned). The detergents, hydrocarbons and phenols penetrated only during the first hours until the bacteria could adapt to the compound used. This suggests that even if higher levels were introduced it is only a matter of time before natural microorganisms will eventually clear up the contaminant, if degradable.

A.3 Paper No. 20

This is a case history of groundwater contamination. Although there are many similar cases in severity and complexity, the efforts made by the author were interesting and commendable. It was rather confusing to the reader and to the listener because the map and figures did not locate many of the reference points, i.e., West Footscray, Stonycreek, the chemical plant, the new treatment plant, the vertical scale in Fig. 2, the Maribyrnona and Werribee rivers. The 90° orientation of the geologic cross sections could probably not be helped, but added to the confusion. It was interesting to see the apparent solution of the phenol and oil problem by utilizing the microorganisms beneath the oil layer by using the discharge-recharge jet flow with the jets located beneath the oil layer. It was also interesting to see that a major mineral degradation in the upper aquifer from the north-northeast resulted from the cone developed at 248, and a lesser plum in the lower aquifer in 1975 from the southeast. This contamination may likely rival the contamination from the north-northeast in time.

B & C Discussions

B & C.2 The prepared discussion of Paper No. 17 concerned buffered water in relation to lead precipitation and something about Australian experiences with contamination with zinc.

A question from the floor pertained to replacement of the successive ground layers between the periods of application of contaminants to which the answer was no. The basins were cleaned with the use of large volumes of water in the intermediate periods.

B & C.3 The prepared discussion and that from the floor (Paper No. 20) pleaded for models for waste disposal control, and suggested desalting brackish water rather than steps to prevent neighboring contamination, the possibility of storage and disposal elsewhere.

D. Other Observations and Comments

D.2 On reflection, it seems to me that this pilot plant investigation should be labeled as an artificial, artificial recharge study, and could better be studied on a 20-year full scale on-going recharge operation such as that using the Illinois River water at Peoria, Illinois. With the current analytical instrumentation capabilities, there is a builtin opportunity to gather some very important data.

D.3 It appears from a National Geographic Atlas that Footscray is a suburb adjacent west of Melbourne and north of Williamstown on the bay, with little open land between. It is probable that no real assessment of the source of mineralization from the northeast and from the southeast can be made. Therefore recharge from new treatment plant facilities may eventually augment rainfall to raise the water level in the local aquifer and reduce the trend of heavy mineralization in time.

IV. CRITIQUE OF SESSION

This was one of the first sessions of the meeting and the Chairman conscientiously adhered to the schedule, and clearly explained and maintained the rules of procedure, with no problems. The prepared discussions were complimentary and recognized the problems of fulfilling perfection with the limited time for presentation. The questions (and suggestions) were courteous and the speakers responded graciously. The authors for both papers (17 and 20) could have used more than the restricted 10 minutes to make the printed paper more clear and avoid some of the questions. Paper 17 received many questions to the end of his period, and Paper 20 was clearly confusing in some aspects from my standpoint, but his responses to the questions were generally to the point. It was a difficult presentation. The research was conducted carefully for both papers and no unreasonable claims were cited.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

My opinion on significance and value are expressed in the Review of Sessions under III D.

I. SESSION

A. Theme of Session: Chlorination, Flocculation and Adsorption

B. Papers Presented:

3. Comparative Evaluation of Commercial Polyelectrolytes for Flocculating Alum Precipitated Domestic Wastewater.
A. Benedek, J. L. Bancsi (Canada)

6. Treatment of Chlorinated Hydrocarbons Wastewater by Activated Carbon Absorption with Steam Regeneration.
Y. Argaman, G. M. Sassu (Israel)

9. A Fundamental Study of the Removal of Polynuclear Aromatic Hydrocarbons from Water During Chlorination.
R. Perry, R. M. Harrison (Great Britain)

12. Chromium Removal with Activated Carbon.
J. I. Kim, J. Zoltek, Jr. (USA)

II. REVIEWER

A. Name: John P. Giesy, Jr.

B. Position and Affiliation: Research Associate, Savannah River Ecology Laboratory
Assistant Professor, Dept. of Zoology
University of Georgia
Athens, Georgia 30601

III. REVIEW OF SESSION

A. Formal Papers

All four of the papers presented in this session represented advances in removing undesirable nutrients or contaminants from wastewater. While none of the papers represented astounding scientific or engineering breakthroughs or new theory, each presented the type of pragmatic information needed to improve water treatment at the treatment plant level.

A.1 Paper No. 3

The manuscript presented flocculation properties of commercially available polyacrylamides indicating the optimum chain length and percent hydrolysis. The authors appraised the relative gains due to reduced flocculation time.

A.2 Paper No. 6

This manuscript did not present a new method for removing chlorinated hydrocarbons from water or a new method of regeneration but did report the effectiveness of these techniques on a process scale. The use of steam generation instead of thermal regeneration resulted in water of the desired quality at lower cost.

A.3 Paper No. 9

This was the most theoretical of the four papers presented in this session. The primary objectives of the work presented were the development of sample preparation and detection techniques for the determination of polynuclear aromatic hydrocarbons (PAH). The authors cautioned that many factors, which are not generally considered, may affect analytical results. The title of this paper is misleading because little material on removal by chlorination was presented in the oral presentation. The manuscript does present data on the kinetics of PAH removal from water by chlorination and the effect of pH and dissolved solids on removal.

A.4 Paper No. 12

This manuscript presented theoretical information on the adsorption properties of chromium on activated carbon. Optimum conditions for Cr adsorption were reported to be the proton (H^+) to Cr^{+6} ratio.

B, C & D. Discussions

B.1 Most of the prepared and floor discussion of Paper No. 3 centered around the relatively small economic gains and overall water quality improvement due to polyacrylamides polyelectrolyte (PAPE) flocculants. The authors addressed these questions by indicating that the most significant gains achieved by PAPE usage would be in the case of overloaded clarifiers where the volume of water processed could be increased while maintaining prescribed PO_4 levels in the untreated water. Another concern of the designated discusser and floor discussers concerned the possible toxicity of PAPE. The author cited several studies which demonstrated that PAPE in current use were not acutely toxic to fish but was unable to field questions on possible carcinogenic properties of these polyacrylamine compounds.

B.2 The designated discussers presented several good points about Paper No. 6. The main concerns were with activated carbon regeneration such as: Do mixtures of organics act similarly to pure compounds? What happens to nonvolatile compounds such as high molecular weight oils which may saturate the carbon and not be regenerated by steam? How can breakthrough of columns be controlled? How many cycles of regeneration can be used?

The author addressed all questions from the designated discusser and the floor well. The author indicated that the columns must be set up in a series of three columns with two in the scavenging cycle while the third is being regenerated. The activated charcoal, in the applied situation presented in this paper, can be used for about 10 regeneration cycles before it must be thermally regenerated.

I feel that technology of this type presently has a number of shortcomings, especially for treating complex organic wastes. The water quality of the effluent water reported in this study was 1 mg/ℓ of polyvinyl chloride. While this is a considerable improvement over raw effluent, work here in the United States has indicated that we should be concerned with μg/ℓ and ng/ℓ levels of synthetic organics in the environment. Another problem with the activated charcoal treatment as practiced is the atmospheric release of organics upon regeneration.

B.3 The designated discusser of this paper did not address the material presented but presented a review of another research program studying PAH breakdown by ultraviolet light. This review indicated that sunlight can cause considerable decomposition of PAH compounds.

Those in attendance at the session were in agreement that the UV decomposition studies were not applicable to natural systems because of variation of pH and total dissolved solids and because the study used detergents and acetone to dissolve the PAH compounds.

Discussion of the manuscript from the floor centered around the importance of studying low levels of PAH compounds in water supplies because they are present at low levels, difficult to detect and very diverse. The author pointed out several studies which had indicated the carcinogenic nature of these compounds at very low levels. Several members of the audience asked what the products of chlorination of PAH compounds might be and whether they might be more carcinogenic than PAH's alone.

B.4 The prepared discussion of this manuscript was the most penetrating discussion given during this session. While most of the floor participants thought the results were interesting, they did not feel that they represented significant advancements in water treatment because of the high cost and near impossibility of controlling the H^+:Cr^{+6} ratio on a process scale.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Using the information presented by the authors of Paper No. 3, individual plant operators can calculate the relative cost versus water volume or retention time costs. The authors conclude that in many routine plant operations, polyelectrolyte flocculants may not improve flocculation over that of alum alone. However, if plant capacity is limited, as is often the case, the use of acrylic polyelectrolytes may increase processing capacity by as much as 400 gal/day/sq ft.

Manuscript No. 6 may be useful for some industrial water treatments. The most interesting discussion of this paper was by people attending the session who thought that activated charcoal may be useful in treating drinking water for the removal of synthetic organics.

Many workers in the United States have been concerned with the detection and identification of PAH compounds in drinking water. Manuscript No. 9 supplies valuable information on the detection and identification of PAH compounds and some insight on their behavior when drinking water is chlorinated.

I. SESSION

A. Theme of Session: Coastal Pollution

B. Papers Presented:

15. Sedimentation of Dispersed Oil in Surface Waters.
M. Thuer, W. Stumm (Switzerland)

18. The Application of a Two-layer Time-Dependent Model to Pollution Assessment and Control in a Short Stratified Estuary.
R. M. Pitblado, R. G. H. Prince (Australia)

21. Preliminary Design of Ocean Outfall at Sydney: Protection of Bathing Waters.
I. G. Wallis, T. J. Pollock, R. W. Whyte (Australia)

II. REVIEWER

A. Name: R. E. Speece

B. Position and Affiliation: Betz Chair Professor of Environmental Engineering
Drexel University
Philadelphia, Pennsylvania 19104

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 15

The intent of the first paper was to cover:

1. Transport mechanism of oil in natural waters
2. Mechanism whereby spilled oil is dispersed
3. Model colloid - chemical interaction and fate

This topic is extremely relevant to U.S. and global interests. Even though the public press focuses attention on the more dramatic oil spills that occur at sea, the less dramatic, day by day addition of oil to inland waters impacts the lives of the U.S. populace to a much greater extent. The relative contribution of oil to the hydrosphere by storm water overflows and sewage treatment plants is much greater than the contribution to the hydrosphere by spills. This underscores the importance of storm water management and unit process design for removal of dispersed oil. Industrial waste codes for management of effluents from automobile service stations and repair garages commonly prescribe treatment by gravity removal and skimming is relatively ineffective.

An understanding of the fate and transport of oil in the hydrosphere is crucial. A complex series of interactions occurs once the oil reaches the hydrosphere. Were it not for these complex interactions, all of the oil would rise to the surface and eventually be deposited at the land-water interface. However, the interaction of the dispersed oil with particulates carried in the natural waters results in a combined density greater than water. This in turn transports the oil to the sediments.

About 10 percent of the oil introduced into the hydrosphere is eventually transported to the sediments in the vicinity of industrialized regions. Great ecological change is created by the oil in the sediments. In aerobic environments, microbial degradation of the oil occurs. Thus, the oil in the sediment encourages the persistence of anaerobic conditions. The anaerobic conditions in turn create an environment whereby precipitated phosphorus can be solubilized and fed back into the overlying water. The end result is that eutrophication can be encouraged.

Fortunately microbial conversion of the oil to carbon dioxide plays a dominant role in the overall picture, destroying approximately 90 percent of the oil entering the hydrosphere. Aerobic conditions are obligatory for microbial oxidation of the oil - the accumulation of natural oil deposits over eons of time attests to their resistance to anaerobic conversion. It is extremely important to recognize that microbial oxidation of the oil must occur in the aqueous phase. This points out the dominant role of extra cellular enzymes to solubilize the oil before it can pass through the bacterial cell wall for oxidation. A vivid demonstration of the dominant role of microbial destruction of oil is found in the relatively rapid destruction of tar balls on sandy beaches. The moist environment allows bacteria to proliferate on the surface of the tar balls and exposure to the air maintains an aerobic environment. The low temperatures prevailing in sediments also retard microbial degradation even if aerobic conditions prevailed. In some aqueous environs, microbial degradation may be retarded due to the lack of an adequate nitrogen source to sustain microbial synthesis.

The atmospheric "rain out" of evaporated hydrocarbons may be a significant pathway to the hydrosphere. However, the lower molecular weight of the fraction lends itself to a much higher rate of biodegradability, which reduces considerably the environmental impact thereof.

The behavior of oil reaching saline, coastal waters was noted to be significantly different than in fresh water - with respect to the coagulation phenomena. The biodegradability phenomenon would not be significantly altered.

The gas chromatographic techniques developed by Blumer at Woods Hole have enabled specific identification of oil types - even to the extent of identifying the specific well source.

There was some controversial discussion regarding the estimated quantities of oil reaching the hydrosphere. An M.I.T. study reported oil losses at 0.1 to 0.5 percent of the total oil transported. Using an estimated value of 0.2 percent would yield about 2,500,000 tons per year to the hydrosphere. Professor Pearson of the University of California stated that the M.I.T. estimate of total losses to the hydrosphere is only about 20 percent of the actual losses. Professor Pearson also confirmed that the relative contribution of oil spills to the hydrosphere was minor. He estimated 8,700,000 tons per year was in flux in the hydrosphere. The oil flux into Santa Monica Bay from sewers discharging therein would account for 1 percent of the world flux - using the loss rate of 0.2 percent of oil in transit. The same would also be true of the Danube River.

A.2 Paper No. 18

The discussion of the two-layer estuary model emphasized that storm runoff was a much more significant contribution than industrial wastewaters. The lower density of the polluted fresh water flowing into the estuary results in most of the BOD remaining in the top layer of the stratified estuary.

A.3 Paper No. 21

The subject of ocean outfalls for wastewater is of considerable technical, political and economic interest. The major obstacle appears to be public acceptance. Techniques for construction of long outfalls were not available until recently. Consequently, the adverse public acceptance of ocean outfalls was generated from experience with short outfalls. In the public's mind, that distinction is not clear.

The bacterial die-off is closely related to the diurnal cycle. Fecal coliform die-off tests showed that the time for 90 percent mortality varied from 1.9 hours in the light to 40 hours in the dark - with other conditions remaining constant. Consequently, the effluent field reaching the shore could be expected to be higher in the morning. Solar variation between summer and winter should be considered. Bacterial standards are normally lower in winter than in summer due to the absence of bathing activity in winter. Initial dilution in the vicinity of the diffuser is normally designed for 400 to 1 dilution.

IV. CRITIQUE OF SESSION

This session on oil in the hydrosphere was quite well received because of the timeliness and pertinence of the subject matter. Oil in the hydrosphere is of intense interest globally. It was quite relevant to quantify the source contribution of oil into the hydrosphere and to note that spills may be of major consequence locally but relatively minor in the long run, overall picture. The need to address the oil contribution from point source sewers was perhaps the most important issue raised.

The session on ocean outfalls was very well received at the conference. The audience had a great concentration of people who were closely associated with actual design and monitoring of ocean outfalls. It was suggested that the dilution and convection models could and should be much simplified.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Regarding oil in the hydrosphere a major effort should be made to develop effective unit processes adaptable to effluents from automobile service stations and repair garages for coalescence filtration. The field operational costs associated with such equipment need to be evaluated to establish the economic impact of such industrial waste treatment codes. Likewise, microbial removal of emulsified oil by secondary treatment processes for municipalities treating wastewaters of domestic-industrial origin needs quantification to establish a national budget for oil contribution to the hydrosphere by sewage treatment effluents.

Concerning estuaries there are many estuaries in the U.S. that would fall into the category of "two-layered." The contribution of pollution from storm events to the surface layer results in relatively short term oxygen depletion. The stagnant bottom layer of the estuary eventually receives the burden of the pollution and often undergoes extended periods of anaerobiosis as a result. Fish life is not possible.

It was quite pointedly demonstrated that agreement between observed and predicted parameters in a model is no gurrantee of the value of the model as conditions change. Likewise with models which have so many inputs - 22 in this case - it is possible to make anything fit the model by adjusting the parameters.

Proper model calibration requires frequent sampling of the entire water column. Helicopters facilitate such sampling.

Regarding ocean outfalls, experience at the Water Pollution Research Laboratory in Stevenage, England, has demonstrated that a great discrepancy consistently occurs between die-off tests in small containers vs. in-situ tests. It is vitally important to utilize drogue floats in determining the shoreward migration of the effluent field. It was pointed out that beach bacterial counts are not dominated by the effect of sewage outfalls. Rather, rivers, storm water and birds are the dominant bacterial contributors.

One very significant point was made that primary sedimentation should be eliminated prior to ocean outfall disposal. The operation of primary sedimentation and resultant sludge disposal problems are not warranted in view of the fact that inclusion of primary sedimentation is not reflected in improved beach conditions. Studies in Britain with properly defined long outfalls have shown that it is impossible to detect sewage 400 meters from the outfall. In sewage with high grease content primary sedimentation may still be important because of the likelihood of grease balls accumulating on the shore.

It is sometimes stipulated in the design criteria that the plume remain submerged 90 percent of the time. This may be a desirable objective, but it is very difficult - if not impossible - to monitor such a standard.

The actual spacing of the diffuser ports is not critical. The main criteria are the discharge per unit length of diffuser and adequate port diameter to prevent plugging. Minimum diffuser port diameter recommended is 7 cm. In shallower depths than about 50 m, it would be more important to insure higher velocity through the diffuser jets to achieve higher immediate dilution ratios.

I. SESSION

A. Theme of Session: Dynamics of Biological Nitrification

B. Papers Presented: 22. Dynamic Nature of Nitrifying Biological Suspended Growth Systems
K. L. Murphy, P. M. Sutton, B. E. Jank (Canada)

25. Design of Nitrifying Activated Sludge Process with the Aid of Dynamic Simulation
W. Gujer (Switzerland)

II. REVIEWER

A. Name: John Cairns, Jr.

B. Position and Affiliation: University Distinguished Professor
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 22

The main point was they found no distinct advantage of combined over separate activated sludge systems. Apparently the model is not generalizable.

A.2 Paper No. 25

The principal value of this paper is the detailed information generated.

B. Prepared Discussions

B.1 The discusser, A. Balaban (Israel) questioned some of the basic data (particularly Table 3 in original paper). Otherwise Balaban's review was perfunctory.

B.2 A. L. Downing (United Kingdom) gave a very favorable review but indicated this was merely an update of some research carried out by Downing and others at Stevenage (United Kingdom) some years ago.

C. Floor Discussions

C.1 The most relevant floor discussion was initiated by Professor Barnes of University Clyde, Glasgow (United Kingdom). Barnes pointed out that getting data good enough to handle by the transfer coefficient equation would require sampling about every 10 minutes (or perhaps more frequently). Paper No. 22 did not have short enough sampling intervals. The question of substantial inhibition (50 percent reduction in growth rate) was acknowledged. Sutton's reply to discussion was that they were not trying to develop a universal model but rather to see how influent variability affects function. This alone seriously limits the utility of this presentation.

C.2 Sutton was the principal floor discusser - the nitrogen loss really not accounted for, the model indicates it should reappear as nitrate. Gujer did not disagree with these comments.

D. Other Observations and Comments

Even with many simplifying assumptions the nitrifying process is still too complex and poorly understood to produce general models with practical utility.

IV. CRITIQUE OF SESSION

No major conceptual breakthroughs (these are exceedingly rare) but generally sound professional research that was mostly well received. Research was original but some models may not be generalizable to other situations.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Techniques and methodology were probably the most useful contributions. Identification of trouble spots (i.e., data collected less frequently than desirable) will help Americans avoid similar errors.

I. SESSION

A. Theme of Session: General

B. Papers Presented: 28. An Integrated Pollution Control System: Combined Clarification of Wastewater and Incinerator Scrubber Effluent and Utilization of Clarified Effluent for Scrubbing of Stack Emissions.
W. J. Weber, Jr., F. L. Snitz (USA)
M. Rebhun (Israel)

31. Design Approach for Effluent Variability Removal in Wastewater Treatment Systems.
V. Novotny (USA)

34. The Integration of Wastewater Treatment with Water Reclamation.
L. R. J. VanVuuren, W. R. Ross, J. Prinsloo (South Africa)

II. REVIEWER

A. Name: James H. Reynolds

B. Position and Affiliation: Assistant Professor, Civil and
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III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 28

Two significant errors in the preprint of the paper were corrected by the authors during their formal presentation of the paper. Figure 1 in the original printed paper (which is incorrect) was identical to Figure 6. Figure 1 of the printed paper should appear similar to Figure 1, Schematic Diagram of an Integrated Pollution Control System, which is attached to this review. The second correction pertains to Figure 4 in the original paper. The label for the upper right hand graph of Figure 4 should read "100 mg/ℓ Alum" instead of "10 mg/ℓ Alum."

The paper is an excellent attempt at combining two separate waste disposal units into one integrated system. This approach to integration of waste disposal systems is a concept which has tremendous merit in nations where waste disposal has reached crisis portions. This is especially true in the United States. Although the particular system discussed in the paper has several drawbacks, the basic concept of integration is farsighted.

The importance of integrated waste disposal systems will become readily apparent as the demand and shortage of our nation's energy resources increase.

A.2 Paper No. 31

This paper described an innovative technique, based on the frequency response approach, for determining the effluent variability of a waste treatment process for a complete treatment plant. Although the mathematical development of the paper is somewhat difficult to understand, the approach for design of equalization basins has significant merit. The author indicated in his formal oral presentation that this paper was intended to be a conclusion of three previous papers published by the same author (Novotny and Englande, Jr., 1974; Novotny, Englande, Jr. and Mojgani, 1976; Novotny and Stein, 1976). Individuals particularly interested in the subject should review the previous publications carefully.

The author indicated that there were three errors in the preprint of the paper. Therefore, the following corrections should be noted:

1) Figures 4 and 7 of the original paper should be interchanged.

2) The title of Figure 5 (original paper) should read: "Variability reduction of a random input to a dispersed flow tank."

3) Equation 7 should read:

$$A(f) = \exp\left(\frac{P}{2}\left(1 - (a^2 + b^2)^{1/4}\cos \alpha\right)\right)$$

A.3 Paper No. 34

The paper presents the results of a pilot scale study designed to investigate wastewater reclamation for reuse. The pilot plant can be operated as an independent physical-chemical plant or in conjunction with biological process units. The preprint of the paper presented the results of five different operational modes studied using this particular pilot plant. During the formal presentation of the paper, the author discussed a sixth operational mode which was not included in the preprint. The sixth mode is outlined in Figure 2 which is attached to this report.

No specific data were presented concerning the performance of Mode VI. However, the authors indicated that it was a highly promising approach and that a full scale report of Mode VI would be published in the near future.

The authors indicated that their primary purpose in the study was to produce a water suitable for unlimited reuse. Their principal reuse parameter was a nitrate-nitrogen level of less than 10 mg/ℓ.

Several of their modes of operation achieved the 10 mg/ℓ nitrate-nitrogen level. However, in all cases the COD concentrations were greater than 40 mg/ℓ. As noted by several discussers of the paper, this high level of COD indicates that there exists a high potential for refractory organics to remain in this water which is intended for unlimited reuse. This will be discussed in more detail in the discussion portion of this review.

This paper reported the successful operation of the denitrification process without an external carbon source. Instead a portion of the raw waste was cycled directly to the denitrification unit, thus providing the needed carbon.

B. Prepared Discussions

B.1 The formal discusser of the paper raised several interesting questions with regard to the research. (i) What chemical dosages would be required? (ii) Is there a potential buildup of heavy metals in the system which could be harmful? (iii) Would there be problems of locating the wastewater treatment plant near the incinerator and vice versa?

The authors responded that (i) chemical dosages would have to be determined on a case by case basis. However, their data indicated a broad range of chemical dosages was acceptable. (ii) Heavy metal buildup could be a problem. However, lime coagulation could solve the problem. (iii) Site selection would require an economic evaluation on a case by case basis.

B.2 The prepared discussion (Paper No. 31) was relatively brief. The discusser suggested at least two other methods for flow equalization. These were (i) control of infiltration and inflow, and (ii) pretreatment of industrial waste. The discusser felt that these methods had been used satisfactorily in the past and inquired if the new approach presented in the paper had been demonstrated on a "real world" system. The discusser also inquired as to the significance of the new approach since the example presented in the paper only reduced the detention time calculated by a standard safety factor method by only 6.7 percent.

The author of the paper responded that this paper was the conclusion in a series of four papers and that applications to at least laboratory scale treatment processes were presented in the previous papers (Novotny and Englande, Jr., 1974; Novotny, Englande, Jr. and Mojgani, 1976; Novotny and Stein, 1976). The author also commented that it was only coincidental that the example presented in the paper resulted in a 6.7 percent reduction. For systems with high variability this new approach would be much more reliable than employing an empirical safety factor.

B.3 The formal discusser indicated that the demonstration of the denitrification process without an external carbon source was very interesting. The formal discusser indicated that a denitrification plant employing methanol as the external carbon source was in preparation near Camberra, Australia. The calculated daily methanol requirement for that plant alone would exceed the total amount of methanol currently imported into Australia.

It would appear that at a time when the cost of petroleum products is extremely high, non-external carbon source denitrification systems should be more fully demonstrated.

C. Floor Discussions

C.1 The floor discussion (Paper No. 28) centered around the portion of the paper which indicated that coagulation-clarification could be accomplished with fly ash only. This aspect will be discussed in detail in the Other Observations section of this report. Most discussers were favorable to the research.

C.2 No comments or other discussion from the floor occurred with respect to Paper No. 31.

C.3 The floor discussion (Paper No. 34) centered more on the issue of reuse in general rather than a direct discussion of the material presented in the paper. The discussion was dominated by delegates from water-short countries such as Israel, South Africa and Australia.

There was considerable discussion concerning the acceptable level of nitrate-nitrogen in the reclaimed water. The authors were holding to a 10 mg/ℓ nitrate-nitrogen level. However, several discussers reported on specific cases where people had been drinking water with extremely high nitrate levels without any harmful effects. For instance, a community in Yemen has been using water with nitrate-nitrogen levels ranging from 200-300 mg/ℓ with no harmful effects. An Australian family has a private water source with nitrate-nitrogen levels ranging from 100-150 mg/ℓ. The family has utilized the water for three generations without any harmful effects.

The high COD levels of the proposed reuse water was of concern to several discussers. High COD levels indicate a high concentration of dissolved refractory organics which are potentially harmful. More research is needed to develop processes which will reduce these substances to safe levels. One discusser reported that in a survey conducted in the United States, within waters with a TOC of from 3-5 mg/ℓ, approximately 250 different organic compounds were identified. The health risks relating to these compounds are not presently fully known.

D. Other Observations and Comments

D.1 The need for the integrated system was expressed by several members of the audience. Four Australian and two South African Conference participants expressed keen interest in the system.

The portion of the paper which gained the greatest attention was the data indicating that municipal wastewater could be successfully coagulated and clarified without chemical addition, i.e., lime or alum, provided sufficient fly ash was present in the scrubber effluent (Figure 6 of original paper, Weber *et al.*, 1977). These data suggested that a substantial savings in chemical costs could be achieved through the integrated approach. However, using fly ash to attempt wastewater coagulation-clarification without additional chemical addition has two potential problems. The first concerns the degree of control and flexibility available to the treatment plant operator. That is, from a practical point of view, it appears that it would be an extremely difficult task to match the scrubber effluent fly ash concentration to the required municipal wastewater coagulant dose.

The second potential problem concerns the availability of sufficient quantities of fly ash to actually coagulate the wastewater. For example, according to the authors 1 to 4 g/ℓ of fly ash is required to achieve adequate municipal wastewater coagulation-clarification. The authors also indicate that a community of 200,000 people would require a scrubber which would produce a maximum effluent of 26,495 m^3/day (7 mgd). This same community would generate approximately 75,700 m^3/day (20 mgd) of municipal sewage. The fly ash dose required to successfully coagulate and clarify this amount of municipal wastewater would range from 74.6 metric tons/day to 302.6 metric tons/day (83.4 short tons/day to 333.6 short tons/day). This would mean that the fly ash concentration of the scrubber effluent would have to range from 2,857 mg/ℓ to 11,428 mg/ℓ. These required concentrations of fly ash seem rather unrealistic. One conference participant from Australia estimated that 300 to 500 metric tons of fly ash/day would be required to treat the municipal sewage of Sydney.

Although the total dependency on fly ash for coagulation-clarification does not seem feasible, it does appear from the authors' data that a potential savings in chemical costs is possible.

There was some concern expressed concerning the release of heavy metals (Cu, Pb, Zn, Mg, etc.) by the fly ash when the scrubber water was integrated with municipal wastewater. However, the authors provided data indicating this was not a serious concern. A comparison between the authors' data and Water Quality Criteria (EPA, 1972) indicates heavy metals should not be a threat to the system unless buildup occurs due to the continual recycle of the water. The authors did not have enough data to indicate the significance or nonsignificance of heavy metal buildup.

D.2 The technique presented in this paper (No. 31) appears to be very innovative. It allows the design of plant performance to be based on statistical variation. That is, instead of plants being designed to meet an absolute mean effluent value, the treatment capability of the plant is designed on the degree of statistical confidence the design engineer wishes to select. For example, instead of designing a plant to discharge only 30 mg/ℓ BOD_5 under all conditions, the design engineer can design the plant on a 95 percent probability that the effluent BOD_5 concentration will not exceed 30 mg/ℓ. This latter approach allows designers to reflect what actually occurs in nature rather than fitting the design to an arbitrary standard.

D.3 Discussion of Paper No. 34 after the formal presentation indicated that the most probable reason for the lack of harmful effects due to the high nitrate-nitrogen in the water in both the Yemen and Australian cases is that infants were not drinking the water directly. In both cases, it was speculated that infants were being breast fed and thus were not directly exposed to drinking the water.

IV. CRITIQUE OF SESSION

The paper by Weber *et al.* was well conceived, written, prepared and presented. The research was extremely original and should be pursued on a large scale. The work generated a lot of good discussion by conference participants. Most of the discussion centered around the need for integrated systems. It was felt that such systems could result in substantial energy and cost savings.

Paper No. 31 was well written, prepared and presented. However, a more detailed example of the application of the technique developed would have helped the audience appreciate its value. The lack of informal discussion indicated that most persons in attendance probably did not fully understand the intent or development of the paper.

This paper (No. 34) was extremely well attended. The authors made a good, clear, concise presentation. However, many of the concerns of the delegates with respect to reuse standards, refractory organics and health risks were not resolved. The paper would have been much better if the authors would have discussed modes of operation in greater detail as opposed to discussing a large number of operation modes with little detail.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The research presented in Paper No. 28 was highly significant to American water pollution research. It represents one of the few attempts at looking toward solving the total waste disposal problem. Historically environmental engineers have attempted to solve pollution problems by isolating different wastes. The idea of an integrated system which combines solid waste disposal, air pollution control, and wastewater treatment into a unified package minimizes the impact of these individual processes. More in-depth study of this concept is needed. Such research could lead to reduced energy cost for pollution control.

The results reported in the second paper have direct application to the United States. The technique developed will allow equalization design based on sound fundamental theory instead of empirical safety factors. However, before the method could be fully implemented, regulatory agencies would have to develop effluent standards and guidelines based on probability of compliance rather than fixed maximum levels. Further research is needed in the U.S. to define the level of confidence or the level of probability which will protect and maintain current water quality levels.

The high COD values reported in the third paper are very significant to the U.S. water research program. As more emphasis is placed on reuse, the need for better methods of detection and removal of refractory organics becomes more urgent. This paper illustrates that water for reuse can be produced but that the health risk of the dissolved organics must be considered.

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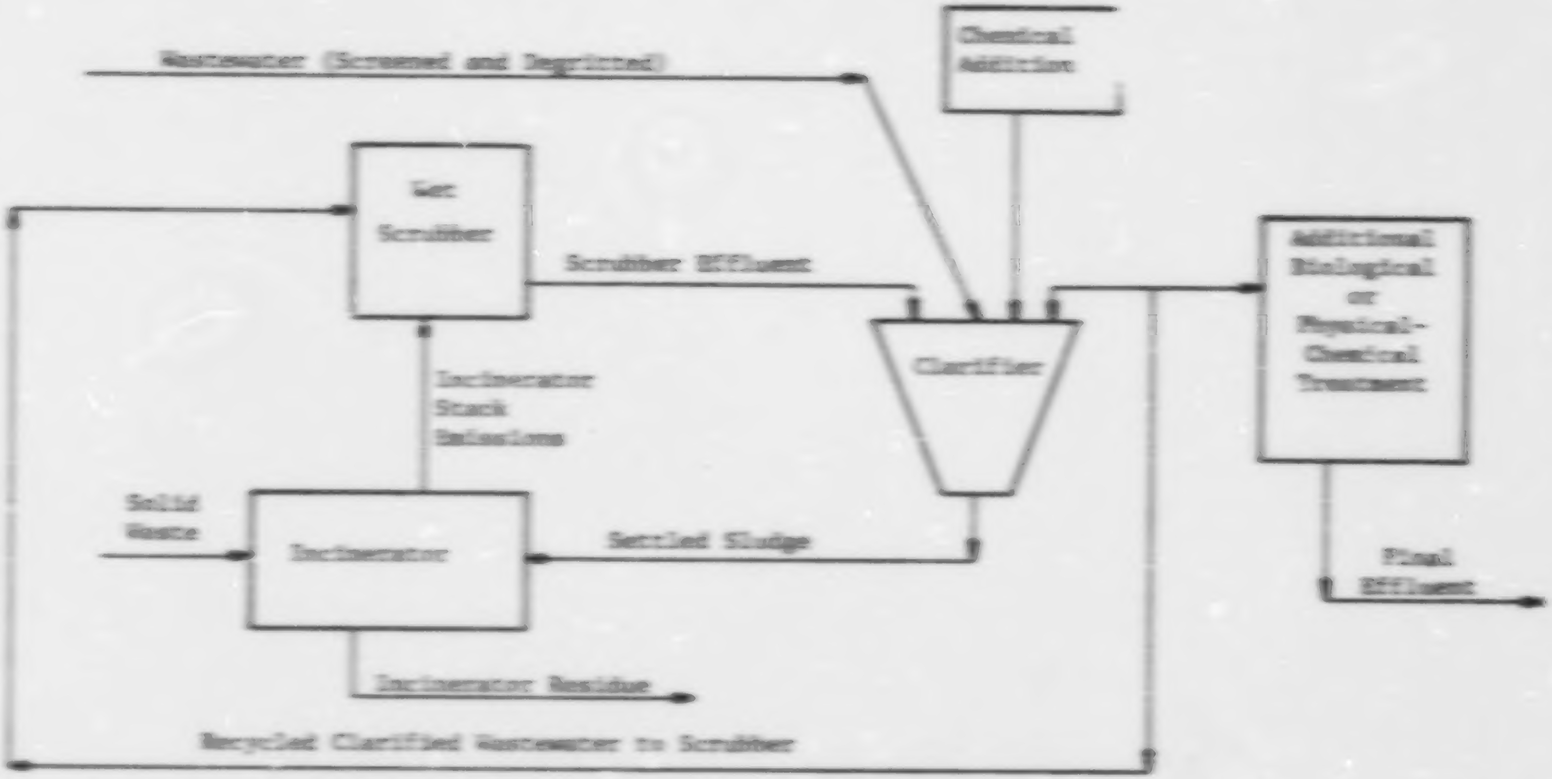
Wastewater (Screened and Degritted)
Chemical Addition
Wet Scrubber
Scrubber Effluent
Clarifier
Additional Biological or Physical-Chemical Treatment
Incinerator Stack Emissions
Solid Waste
Incinerator
Settled Sludge
Final Effluent
Incinerator Residue
Recycled Clarified Wastewater to Scrubber

Figure 1. Schematic diagram of an integrated pollution control system. (After Weber, Seitz, and Rebhun, 1977) omitted from original paper.

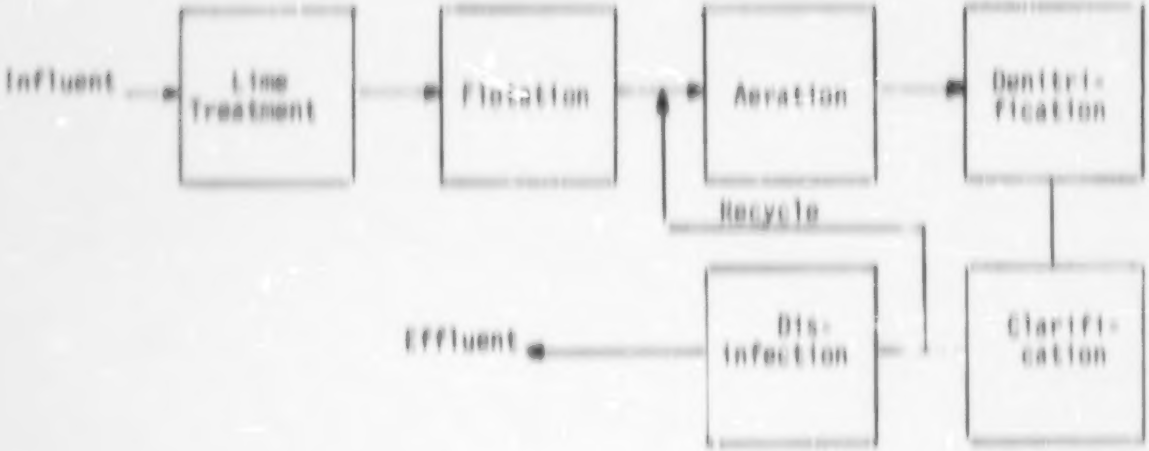

Figure 2. Mode VI: LFB process without ammonia stripping

I. SESSION

A. Theme of Session: Ultimate Disposal of Sludges, Toxic Wastes, and Strong Organic Liquors - Impact of Various Sludge Disposal Alternatives on the Environment

B. Papers Presented: Workshop - Ultimate Disposal of Sludges, Toxic Wastes and Strong Organic Liquors.
Convener: G. E. Eden
Speakers: L. Ulmgren (Sweden), G. A. Carthew (Australia), and B. Lynam (USA)

II. REVIEWER

A. Name: Davis L. Ford

B. Position and Affiliation: Senior Vice President
Engineering-Science, Inc.
Austin, Texas

III. REVIEW OF SESSION

A. Formal Papers

A.1 B. Lynam of the U.S. presented a paper in the convened workshop dealing with the various aspects of ultimate sludge disposal practiced by the Chicago Metropolitan Sanitary District in Fulton County. He first discussed a sludge reclamation which should be practiced when beneficial use is a possible resultant. He cited the application of heat-treated sludge to citrus and cotton areas in the state of Florida, natural gas being used for heat treating the sludge which was subsequently dewatered on vacuum filters with chemical conditioning. The storing and recovery of dried sludge was cited, the sludge being stored for years in deep quarries with water monitoring systems for both surface runoff and ground water. Monitoring of methane gas was also involved. The long-term storage made the sludge more acceptable, as there was complete destruction of pathogens during the freeze and thaw cycles. The liquid sludge was applied to the land by vehicles, and the public acceptance of this overall disposal technique was underscored. The monitoring of the heavy metal content in sludges was also mentioned. The speaker cited the fact that corn has been produced using these sludges as fertilizer and sold on the open market, as well as soybeans, wheat and other feed grains.

A.2 L. Ulmgren of Sweden also discussed the land application of sludges. He indicated that municipal and industrial waste sludges were often treated jointly with positive results. The metal processing industrial sludges cause various problems and pretreatment was required to facilitate sludge disposal. Temporary storage of sludge inventories during the winter months was required because of the frozen ground and the sludge could not be applied during this period. He indicated that as no ocean disposal was permitted, the industrial sludges were conditioned with lime and stored or disposed jointly with municipal refuse. The municipality is responsible for disposal of these sludges when combined with refuse and the limit of application is one metric ton per hectare per year with the possibility of every five years applying as much as five metric tons per hectare per year.

A.3 G. A. Carthew of Australia discussed lime recovery via recalcination of sludges generated from the lime precipitation of raw sewage. This sludge is dewatered via centrifugation and burned in a multiple-hearth furnace. The centrifuged solids capture rate was 35 to 60 percent, but decreased with time resulting from abrasion and wear on the scroll unit. It was indicated that the recycled lime from this recalcination process produced better phosphorus and BOD removal in the primary units as compared to the use of virgin lime.

B. Floor Discussions

There were several discussions from the floor during the workshop session. Balitho from South Africa cited South African experience in land disposal indicating that this practice had been followed for 60 years near Johannesburg. He stated that the disposability of sludge was highly related to the antecedent processes, citing for example that the maintenance of sludge under aerobic conditions at all times minimized subsequent phosphorus release. He also stated, for example, that high ammonia levels in the sludge may overload the nitrification capacity of the soil, resulting in chlorosis in plants. Approximately 7000 to 8000 animals in a test population under close veterinary control were grazing on the land to which the sludge was applied. He cited that the ascaris is not carried through the plants to humans as the crops go to silage or feed for the cattle. He further stated that inactivation of the ascaris with Cobalt 60 is complete at a cost of $3/ton.

D. Cohen of Canada presented the next discussion from the floor. He cited the sources of industrial sludges in Canada which include those from the production of pulp and paper, textiles, petroleum, mining, organic chemicals, and inorganic chemicals. He indicated several instances where waste sludges were used for fuel without adverse effects on equipment.

A representative of Lurgi (Australia) discussed incineration of waste chemical sludges and the energy conservation realized by the use of these sludges. He also discussed the incineration of chlorinated hydrocarbons at high temperatures, high moisture contents and low oxygen levels. The application of industrial sludges on sand dunes was also discussed including the monitoring techniques used in detecting impurities in the ground water which pick up the leachate. Submersible pumps were lowered into bore holes to enable sampling in single holes.

C. Responses and Other Observations

Ulmgren of Sweden indicated that the uptake of heavy metals in plants had been reviewed for several years in Upsalla, Sweden; however, there are no published data at this time. Lynam of the USA discussed the current restrictions of applying sewage sludge for land application because there are no universally accepted values for all types of sludges and soils. He indicated that the limitations for sludge application of land are specific for the particular site and the characteristics of the sludge. The control of industrial wastes into sewers was mentioned, using industrial waste ordinances and pretreatment requirements for control. He also alluded to the fact that industrial waste sludge disposal problems were many, including those associated with heat treatment, injection wells, leaching from landfill sites and contaminating ground waters, and persistence of conservative components of sludge in the environment.

IV. CRITIQUE OF SESSION

It is interesting to note that the thrust of the conversation of both the papers and discussions in this session seemed to emphasize in one form or another the land application of liquid sludge. The trend seems to be away from ocean disposal, and the energy situation in many countries has mitigated the attractiveness of incineration of sludges, particularly those of low BTU value. There was emphasis throughout the discussion of the uptake of certain conservative constituents such as heavy metals in forage crops and feed grains which have been fertilized by liquid sludge as well as potential ground water contamination resulting from the land application of waste sludges. There was obviously some overlap between this session and that conducted on Thursday morning, October 21, entitled "Land Treatment."

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

As indicated in Section IV of this report, the emphasis of the ultimate disposal of sludges appeared to be directed toward conventional dewatering processes using heat treatment and/or chemicals and land application. Although this is obviously prohibitive in many of the more densely settled areas of the United States, it appears that an emphasis on research activities could include the following directly and indirectly related topics:

1. To evaluate the efficacy of selected land disposal of both municipal, industrial and municipal/industrial sludge blends, particularly in land areas where the fertilizer value of the sludge can be realized.
2. To develop a better understanding of the impact of antecedent unit processes on the sludge characteristics and the implications of these processes in removing nutrients prior to land application.
3. To develop a cost-effective evaluation of the various ultimate disposal alternatives including land disposal following sludge treatment and dewatering, ocean disposal, and the incineration of sludges, possibly reclaiming given constituents in selected cases.
4. To assess formulation of optimum solution regarding land farming of sludges by maximizing the conditioning of sludge for adequate

dewatering and handling while minimizing the ultimate impact of the conditioners on the soil and crops.

5. To perform specific research studies in evaluating the effect of heat treatment reaction temperature and retention time on specific resistance as well as the evaluation of other variables which influence the dewaterability of sludges. This is particularly important when realizing that the capital and operating costs of the sludge handling facilities could constitute 30 to 40 percent of the total cost of the wastewater treatment facility.

6. To make comprehensive studies of the fate of enteric bacteria and enteric viruses contained in sludge when applied to the land. Additional studies are warranted in determining the survival of pathogenic microorganisms in crops used both for human consumption and as feed grains and forage for livestock.

7. To develop information tracing the uptake and removal of heavy metals from sludges to various soil types and specified crops. An attempt to quantify the profile of heavy metals transferred to soil and various crops, establishing a mass balance if possible, would be helpful in establishing the basic information to determine the overall impact of heavy metals contained in land-applied sludges on the receiving environment.

8. To develop a comprehensive energy analysis of heat treating, of dewatering, incinerating and reclaiming specific constituents from both municipal and industrial sludges. This energy consumption should be put in perspective of the overall energy requirements associated with both BPTCA and BAT levels of wastewater treatment facilities.

9. To make an evaluation of the land application of liquid sludges in terms of the soil classification and temperature impacts on this form of sludge disposal. It is recognized that a good portion of both municipal and industrial sludges are generated in areas with sterile soils and/or severe climatic conditions. A sludge quality-soil characteristic-soil temperature interrelationship would be helpful in formulating decisions relative to the ultimate disposal of sludges.

10. To consider more seriously not only the land application of liquid sludge but also the application of partially treated wastewater, particularly in the arid and semi-arid land areas of the United States. Although this at first glance appears to be an antiquated concept with public health hazards, this concept under proper controls has potential merit in water-limited areas. Of particular interest is the land application of untreated sewage and industrial waste at the Werribee Farm near Melbourne, Australia.

These are some of the more prevalent areas of research which were discussed at the Conference. Although it is recognized that some of these topics have or are being investigated to some extent, a comprehensive review of the aforementioned topics in terms of establishing new areas of research can be considered.

I. SESSION

A. Theme of Session: Sludge Thickening and Dewatering

B. Papers Presented: 23. Continuous Thickening of Sludges.
P. Kos (USA)

II. REVIEWER

A. Name: E. Robert Baumann

B. Position and Affiliation: Professor of Civil Engineering
Iowa State University
Ames, Iowa 50010

III. REVIEW OF SESSION

A. Formal Paper

A.1 Paper No. 23

Flocculent suspensions form three different zones in continuous flow thickeners: a zone of clear liquid, a zone of sedimentation, and a zone of thickening. Sludge entering a thickener is partially dispersed in the sedimentation zone and flows as a density current in the lower part of that zone. The solid phase of the sludge creates flocs which settle to the top of the thickening zone, lose their individual character, and become part of the matrix of solids compressed by the pressure of the overlying solids. The water in the thickening zone must flow upward through the matrix of solids -- and through channels in it -- as the matrix is compressed. Design of a thickener requires determination of thickener cross sectional area for sedimentation of the flocs in concentrations up to the boundary condition, i.e., the concentration of the floc in the upper boundary of the thickening zone, and thickening the sludge in the sludge compression or thickening zone. With wastewater treatment plant flocculent suspensions, the area required for thickening controls the thickener design. Unfortunately, Kos states, "there is not at the present time a reliable simple test procedure for thickening zone area and depth evaluation."

The action in the thickening zone is a consolidation process and can be described by studying the filtration and deformation properties of thickened materials. In other words, gravity thickening in the thickening zone is a flow (filtration) of liquid through a deforming saturated flocculent porous matrix. There are various theories which describe such liquid flow through non-rigid or deformable media. Kos studied transport of mass and momentum in porous media and concluded that, for gravity thickening, the model of a media with point contacts between particles is applicable. He developed two equations:

1. Conservation of mass principle for steady state thickening

$$(v_s - v_f)n = \frac{Qu\,Cu}{A}\left[\frac{1}{C(X)} - \frac{1}{Cu}\right] \qquad (1)$$

where v_s = average solid vertical velocity relative to tank

v_ℓ = average liquid vertical velocity

n = porosity

Qu = rate of underflow

Cu = underflow solids concentration

Cx = concentration at depth x

A = cross-sectional thickener area, and

$(v_s - v_\ell)n$ = superficial settling velocity

2. Summation of force balances of solid and liquid phases

$$\frac{d\sigma}{dx} = \frac{d\sigma_T}{dx} - \frac{dp}{dx} = d_\ell g_x + g_x(1 - \frac{d_\ell}{d_s})C(x) - \frac{dp}{dx} \qquad (2)$$

where σ_T = total pressure

p = liquid phase pressure

g_x = acceleration of gravity

d_ℓ = density of liquid

d_s = density of solid

Integration of the second equation gives

$$\sigma_T(x) = \sigma(x) + p(x) = g_x d_\ell x + g_x(1 - \frac{d_\ell}{d_s}) \int_0^x c(x)\, dx \qquad (3)$$

The total pressure at depth x, $\sigma_T(x)$, is the weight of overlying suspension per unit of area. The effective pressure, σ, is the fraction of total pressure transmitted through particle contact. The liquid pressure, p, consists of the hydrostatic pressure and the excess hydrostatic pressure (u-pressure). Similarly, the u_T-pressure can be defined as the total minus hydrostatic pressure:

$$u_T(x) = \sigma_T(x) - g_x d_\ell x \qquad (4)$$

Thus, the liquid force balance relates the liquid pressure gradient (dp/dx) to the relative velocity of solid and liquid phase ($v_s - v_\ell$). The simplest relationship is Darcy's law:

$$\frac{dp}{dx} = d_\ell g_x + \frac{\mu}{k(x)} (v_s - v_\ell)n \qquad (5)$$

where μ = dynamic viscosity

k = intrinsic conductivity, $k' = \frac{\mu K}{d_\ell g_x}$

where K = hydraulic conductivity

Hydraulic conductivity is a function of porosity, n, for compressible materials. When this relationship does not hold, the flow is non-Darcian, and the "filtration characteristics" K is a function of other parameters like $(v_s - v_\ell)$ or different forms of dp/dx versus $(v_s - v_\ell)$ relationships are used. Only experimental work can show the kind of relationship existing between the pressure gradient and relative velocity of solid-liquid phases in thickening operations.

For a full description of the thickening model, we must have a mathematical description of compressive behavior (deformation) of the solid matrix in high concentrations. As in soil consolidation

$$d\varepsilon = a\, d\sigma$$

where a is the modulus of linear compressibility;

$$a = a(\sigma)$$

Again, the stress-strain relationship must be determined experimentally.

In order to determine the "filtration chracteristic" and the "stress-strain" characteristics of thickening zone sludges, laboratory tests must be made in a continuous-flow, steady-state thickener. During steady-state, the solids concentrations and pressure distributions are steady for relatively long time periods making it easy to take reliable measurements which can be compared to computer simulated results. Steady-state conditions are provided when:

1. The solids inflow equals solids leaving in the underflow and the thickener overflow.

2. The interface between sedimentation and thickening zones does not move.

3. The distribution of solids concentration with thickening zone depth is stable.

Data were collected in a 29 cm ID column 253 cm long equipped with a center inlet well and a bottom sludge rake. Water treatment plant sludge was used to demonstrate the theory developed in the paper (36 mg/ℓ of alum, 10.5 mg/ℓ of powdered activated carbon used to treat surface water).

In the laboratory experiments, 12 different steady-state runs were established, maintained for a few days to assure steady-state, and readings and sludge concentrations were measured twice. Readings consisted of:

1. Solids concentration profile with depth (100 mℓ of sludge withdrawn at depths 10 cm apart after all other readings were made).

2. Excess hydrostatic pressure ($\bar{p}$-pressure) profile with depth. The excess hydrostatic pressure measurement was made using piezometers connected to the settling column at various depths. A "Statham" Low Pressure Accessory (SLPA) capable of pressure measurement in the range of 0 to 0.1 psi was placed a few mm below the water level in the settling column. The pressure piezometers were connected to separation cells which in turn were connected to the SLPA. The separation cells kept column solids out of the tubes. The ($\bar{p}$-pressure) at a certain depth was obtained by connecting the SLPA to that depth and reading the portion of the piezometric pressure above datum. Then, the portion of the hydrostatic pressure above datum was measured by connection of the reference port with the SLPA. The reference port was located just below the water level.

3. The σ_T-pressure profile. The measurement of the total minus hydrostatic pressure, σ_T, was carried out using the same arrangement as the ($\bar{p}$-pressure) measurement. Experimentally, the solid matrix can transmit an effective pressure only in the range from 0 to 100 dynes/cm^2 (0.0015 psi). The solid structure is easily destroyed (mixing, vibrations, etc.). Thus, with matrix destroyed, the pressure at a port is the pressure of the whole column of suspension above that port -- or the total pressure.

Kos presented his data in "raw" form in two graphs (Figure 5 of original paper):

1. Height of thickening column, cm, vs. suspended solids concentration, g/ℓ.

2. Height of thickening column, cm, vs. pressure, dynes/cm^2.

The former graph showed the variation in thickened solids concentration with depth for each of three steady-state runs. The latter graph showed both the total pressure, σ_T, and excess hydrostatic ($\bar{p}$-pressure) for each of the same steady-state runs.

To evaluate the "filtration characteristics" of the sludge, Kos calculated the superficial velocity (Eq. 1) for various sludge concentrations and plotted Figure 6 (original paper),

$(v_s - v_\ell)n$, cm/sec vs. excess hydrostatic pressure drop, dynes/cm^3.

(The water sludge data were non-linear; therefore, the sludge is non-Darcian.) Two models were developed to express the filtration properties of the sludge:

1. $(v_s - v_\ell)n = A'(\frac{d\bar{\sigma}}{dx})^{B'}$ (9)

where A' and B' are filtration characteristics, dependent on sludge concentration.

2. A "capillary tube model" (10),(11),(12)

The diameter of the "imaginary capillary tube" as a function of the shear stress on the wall of the capillary tube was shown in Figure 7.

To obtain the sludge "consolidation" characteristics, values of effective pressure, dynes/cm^2, obtained from all steady state conditions were plotted against suspended solids concentrations, g/ℓ (Figure 8). The following equation was used to represent the C-σ relationship:

$$C = C_b + \bar{A}\,\sigma^{\bar{B}} \qquad (13)$$

where $\bar{A}$ and $\bar{B}$ are constants.

The curve defined by this equation was fitted to the data in Figure 8 to give the following equation:

$$C = 8.0 + 0.7645\,\sigma^{0.7578} \qquad (14)$$

where C is in g/ℓ and σ is in dynes/cm^2. This equation says that the varying structure of the flocculent porous medium is due to varying flow conditions (represented by shear stress on the capillary wall). Thus, consolidation of the porous media solid phase is a function of both the shear stress on the wall of the imaginary capillary tubes and effective compressive pressure.

To apply theory to design, a computer program was written to simulate continuous-flow gravity thickening. The simulated results can be plotted to show:

> depth of thickening zone, cm, vs. concentration of thickened sludge, g/ℓ, for any given level of tank solids loadings, kg/m^2 hr (Figure 9)

The laboratory data upon which the computer simulation is based are also plotted to demonstrate conformance of the simulation with the model. The computer simulated data can, for the case of a fixed depth of thickening zone, be adjusted to provide a plot of:

suspended solids loading concentration, g/ℓ, vs.
underflow solids concentration, g/ℓ (Figure 10)

This plot provides a record of the maximum solids loadings associated with maintenance of a given underflow concentration.

It was concluded that sludge thickening occurs because the solid phase in the form of a matrix is compressed by the pressure of the overlying solids and the released water flows upward through the media and channels in it. The process is a flow of liquid through a deformed saturated media which has very specific filtration and deformation properties which can be measured and used in thickener design.

B. Prepared Discussion

Y. Argaman (Israel) pointed out that sludge thickening is a unit process that has wide applications in both water and wastewater treatment applications. Although the cost of thickening is not very significant in overall treatment costs, the success or failure of the process has very significant effects on other treatment processes. For example, activated sludge treatment secondary clarifiers which fail in their thickening function cause failure in secondary biological treatment.

Argaman congratulated the author on making a significant contribution to thickener process understanding. Currently, laboratory studies are made to determine the zone settling properties of a sludge (settling velocity of the interface) from which a solids flux vs. underflow solids concentration curve similar to Kos' Figure 10 are drawn. While this empirical approach is adequate for design, the process is handled as if it were a settling process. This is not, however, a settling process and Kos' analysis provides more insight into what is actually taking place. Unfortunately, Kos' doctoral thesis was not available to review in depth the basis for his mathematical models.

The Kos approach has several advantages which were not emphasized in the paper in that it allows a designer or plant operator to predict the effects of thickener depth, solids loading variations, particle sizes, etc. on the process efficiency.

The Kos procedures have several distinct disadvantages as compared to those of R. I. Dick:

1. The collection of the required data requires larger volumes of sludge and requires that at least 6 to 8 different runs be made over a steady-state period of several days (12-24 days total). It is doubtful if pilot plant sludges would be available in sufficient quantity or quality to complete the tests required for plant design.

2. The tests needed to generate Figure 9 - type curves (depth vs. concentration of thickened sludge for various levels of solids loading) are elaborate and not very practical.

3. There is need to extrapolate the curves using a rather involved computer program.

The Kos approach represents a more scientific step in the right direction in developing a more accurate mathematical model of the continuous-flow, steady-state, gravity thickening process. Further studies are needed, however, to make it practical. For example, studies of the variations in the filtration-consolidation characteristics of full-scale plant sludges and correlation with gravity thickener operation would be of value.

C. Floor Discussions

Dr. Eden (UK). The Kos studies should be expanded to correlate the results of pilot plant tests with full scale tests. Knowing the depth of thickening, is there a simplified design procedure that could be used with Figure 9 based on solids retention time?

R. I. Dick (US). Dick commended the author and discussed briefly the implications to design. The Coe-Clevenger-Kinch models are based on solids concentrations below the zone settling interface. Dick questioned: 1) whether the traditional design approach would, as a practical matter, be in error by ignoring the interparticle forces; and 2) what is the significant limiting solids concentration?

Skinner (Australia). Skinner asked for an estimate of the error possible in design using current thickener design methods.

Reply - The main result of the Kos paper should be to dismiss once and for all time the myth that sludge thickening is a sedimentation process. The rate-limiting process is filtration. The Kos method can be used in thickener design, but lots of sludge is needed.

Fitch and Kos are about to publish an article on "How to Use Batch Data to Generate Figure 10." The sludge thickening design approach will appear soon in a Filtration/Separation (British) Review article. There are no data in the lower region of Figure 6 since suspensions cannot exist in that region.

Lines of equal detention time running from the right downward to the left cutting the solids loading curves can be drawn in Figure 9. Detention time, however, is of secondary significance because you cannot design a thickener based on detention time. In Figure 5 the line with the steepest solids concentration vs. depth line would provide the limiting solids concentration.

It is hard to estimate errors in traditional thickener design assuming the Kos approach provided accurate results. For flocculent solids, however, the estimated error in use of traditional methods would be up to 200-300 percent, the result being underdesign. For mineral applications, traditional methods would result in thickener overdesign by 50 to 200 percent.

IV. CRITIQUE OF SESSION

Kos' paper represents a new fundamental approach to thickener design based on scientific principles. The thickening process is not a sedimentation process even though current laboratory studies on which thickener designs are based are conducted by measuring the sedimentation rate of the interface at the top of the zone settling sludge layer. Kos clearly demonstrated that the filtration and deformation properties of sludge are critical in affecting sludge thickening. His data are convincing.

The paper does not detail in depth the development of the various mathematical models used in the paper. The continuous-flow, steady-state laboratory tests require large volumes of sludge and 10 to 15 days to complete. Thus, use of the Kos model as presented in everyday thickener design is impractical. No correlation of theoretical laboratory continuous-flow thickener results with plant scale results were provided and, evidently, have not yet been attempted. Kos did indicate that a paper describing how to use "batch thickener" test data for design would be published shortly in the Filtration/Separation Journal (Br.).

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

With the new requirements for water treatment and improved secondary and tertiary wastewater treatment, the need for thickening larger volumes of sludge is increasing. In activated sludge treatment, the frequent failure of secondary clarifiers in providing a thickened sludge for recycle has led to the use of flotation thickeners in place of gravity thickeners.

The Kos paper has described a more fundamentally sound method of collecting pilot plant (laboratory) data on which to base the design of gravity thickeners. Further studies must be made to make the new basis for design practical:

1. The laboratory tests must be refined to provide the required design data with less sludge and in shorter time periods. Batch test data may provide this possibility.

2. The design approach must be verified in plant scale evaluations of the accuracy of the design approach. In fact, the approach may be effective, when combined with computer extrapolation of the data, in improving the operation of an existing thickener.

I. SESSION

A. Theme of Session: Sludge Thickening and Dewatering

B. Paper Presented: 26. Dewatering Properties of Lime Stabilized Sewage Sludges.
B. Paulsrud, A. S. Eikum (Norway)

II. REVIEWER

A. Name: E. Robert Baumann

B. Position and Affiliation: Professor of Civil Engineering
Iowa State University
Ames, Iowa 50010

III. REVIEW OF SESSION

A. Formal Paper

A.1 Paper No. 26

Paulsrud presented the paper briefly. In Norway, raw primary sewage in small plants is stored for extended periods before further treatment or land disposal. Lime is frequently added to control odors and to reduce anaerobic digestion. Since lime does not affect the organic material but simply reduces biological action, it was deemed desirable to conduct studies of the effect of storage time on the dewatering properties of lime-treated raw sludge.

Raw primary sludge (2 samples), mixed primary-chemical (alum) sludge, mixed secondary-chemical (alum) sludge, and septic tank sludges were treated with 0 to 600 g $Ca(OH)_2$ per kg total suspended solids and stored for periods of 0 to 28 days. Samples were removed at 0, 1, 4, 7, 14, 21, and 28 days to evaluate:

1. Changes in pH

2. Changes in sludge specific resistance

3. Changes in sludge drainability on a small sand filter

4. Changes in sludge conditionability with a standard polymer (Praestol 444K) as measured by the CST (capillary suction time) test

The test results indicated that to preserve sludge drainability characteristics, the sludge should retain a lime-induced pH greater than 11 for at least 14 days in an open beaker at 20°C. The lime dosage required was as follows:

Sludge	Lime Dosage Required g $Ca(OH)_2$/kg TSS
Raw Primary	200
Mixed Primary-Chemical	300
Mixed Secondary-Chemical	400
Septic Tank	100

Initially the addition of lime reduced the specific resistance of all sludges proportional to the lime dose. If the pH of the sludge decreased with time due to biological action generated during storage, the specific resistance of the sludge increased with time. If the pH did not decrease below a pH of 11, the 0 time specific-sludge resistance was maintained during 28 days of storage at 20°C. Only the chemical sludges provided a specific resistance; however, that was low enough (less than 10^{12} m/kg) to provide effective dewatering of the stored sludge on a vacuum filter or filter press when the lime addition was the minimum required to stabilize the sludge during storage.

The sludge drainage rate (mℓ of filtrate/hr) on a sand filter decreased as a function of storage time when mixed primary-chemical or secondary-chemical sludges were drained, even though these sludges had a specific resistance that was in the range where vacuum filtration would have been successful.

With all of the lime stabilized sludges, the dosage of polymer had to be increased as storage time increased, regardless of lime dosage, in order to obtain a CST value of 10 to 20 seconds recommended for sludge treatment. This is due either to production of organic acids where the pH decreased below 11 or due to possible hydrolysis of organic matter when the pH remained above 11 as recommended. With the primary sludge, the polymer dosage required increased as the lime dosage increased.

It was concluded that:

1. Lime-treatment of raw and mixed sewage sludges to a pH above 12 after storage for 28 days will improve and maintain sludge filterability.
2. Lime additions for stabilization will not give proper conditioning for dewatering by filtration.
3. Sludge drainage of lime-stabilized sludge will increase with increase in lime but decrease again during storage.
4. The decrease in drainage rate did not affect the total volume of water that could be drained from the sludge.
5. The conditioning of lime-stabilized sludge with high MW polymers will require an increased polymer dosage with increased storage time.

6. Primary sludges required higher polymer dosages with higher lime additions; the opposite was true with mixed primary-chemical and mixed secondary-chemical sludges.

B. Prepared Discussion

R. I. Dick (USA) pointed out that lime stabilization both reduces odor and bacteria; however, the effect is only temporary. The authors indicate that the lime dosage for stabilization is inadequate for sludge conditioning. Do the authors therefore recommend use of additional lime for conditioning or the use of lime plus a conditioning chemical?

Dick suggested that basic concepts need to be identified in evaluating the test results:

1. The authors called for a pH of 12 for stabilization. How confident are they in selecting this value?
2. In the primary sludge conditioning with lime and polymer, continued stirring seemed to improve dewaterability of the sludge. Does this indicate inadequate contact between sludge and polymer earlier?
3. The paper included no data on the compressibility of the sludge. Did the authors collect any?
4. What is the most cost effective way of handling sludges of the type tested? Using auxiliary chemicals or not?

C. Floor Discussions

David Barnes (Australia). Did the authors look at the quality of the water drained from the sludges? His experience was that you get a highly polluting return flow using the treatment approach discussed in the paper.

Ron Hicks (NZ). Can animal wastes be limed using the treatment described and sprayed onto land?

Reply - No studies were conducted by the authors of the cost effectiveness of lime-stabilized sludge. Webb in England found that when using lime for stabilization, you also need to use copperas or polymer in combination with lime. When using centrifuges, polymers are also needed.

The basic parameter has to be the effect of pH and it is and was the only parameter of concern. In fact, it was the only one recorded. CST times decreased with longer stirring time because mixing with the higher dosages is less effective and longer mixing times are required. Yes, it is a mixing problem. Unfortunately, sludge compressibility was not measured.

Hydrolysis of organic matter will take place at a high pH and produce a highly putrescible filtrate water. It was not considered in the paper, but is a problem in Norway.

The authors have no experience with lime-treating animal wastes but you should have no obnoxious odors with lime at pH 12, except for ammonia which would be released at that pH.

IV. CRITIQUE OF SESSION

This paper received generally a so-so reception, principally because the use of lime-stabilization and storage of sludge is not an accepted practice in the U.S., Australia and most developed nations. The test results seemed to merely confirm experience of most of those who had ever used the process.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

This paper would appear to have no significance to U.S. practice or need for research activity.

I. SESSION

A. Theme of Session: Pyrolysis of Sewage Sludge and Refuse

B. Papers Presented:

29. Studies on Pyrolysis Process of Sewage Sludge.
    T. Majima, K. Tadao, M. Neruse, M. Hiraoka (Japan)

32. Combined Disposal of Sewage Sludge and Solid Wastes by the Pyrolytic Process.
    N. Brovko, R. A. Lockwood, R. R. Bowerman, K. Y. Chen (USA)

35. Disposal of Sludge Using Solid Wastes as Fuel with Resource Recovery and Creation of Gas End Product for Utility Use.
    T. L. Bogert, D. S. Greene (USA)

II. REVIEWER

A. Name: John Zoltek, Jr.

B. Position and Affiliation:

Associate Professor
Department of Environmental Engineering
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Gainesville, Florida 32611

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 29

The first paper dealt with the pyrolysis of raw sewage sludge that was vacuum filtered with calcium hydroxide and ferric chloride as chemical aids. A 25 kg of dry sludge/hour pilot plant was used to determine the feasibility of two pyrolysis processes, noncombustion and partial combustion. The paper presented much detailed data, and should be very useful for those interested in this subject. Solids reduction was approximately the same as what would be achieved with incineration, about 50 percent. For comparison with the pyrolysis runs an incineration experiment was carried out at 800°C in an electric furnace. It was found that 34 percent of the total Cr was oxidized to Cr^{6+} in the incineration process. In the noncombustion and partial combustion processes the amount of total Cr oxidized was negligible. Apparently, this was a very important consideration in Japan, and rightfully should be considered in the United States. The pyrolysis process produced an objectionable odor, but this odor was decomposed by secondary combustion. Pyrolysis utilized two-thirds as much fuel when compared to incineration, due to the heat value of the gas produced by pyrolysis. The quantity of water used for scrubbing was rather large, but analyses indicated that it was relatively free of pollutants.

A.2 Paper No. 32

The second paper dealt with the pyrolysis of sewage sludge combined with refuse. The experiments were performed on a small laboratory type pyrolysis unit and it is questionable whether the data can be directly scaled up for prototype use. Theoretical calculations were made to determine what gaseous end products would be formed at different pyrolysis temperatures and these theoretical values were found to be substantially different from what was observed in the experimental unit. This discrepancy probably was a result of the small size of the unit as well as poor heat transfer at the surface of some of the solid particles. It was estimated that primary sludge must be dewatered to at least 22 percent solids for the pyrolysis of the combined sludge and refuse to be economically feasible. The moisture content in both the sludge and refuse was the most important economic parameter for heat recovery and efficiency.

A.3 Paper No. 35

The third paper dealt with an engineering-calculation type of study on the disposal of sludge using solid waste as fuel. The primary objective was creating a gaseous end product that could be sold to a utility for its heat value. No experiments were performed, other than analyses on raw sludge and refuse. The process used pure oxygen (20 percent of feed by weight) and the ash was in a slag form that was readily disposable by use for road construction, landfilling, etc. This slagging type of pyrolysis unit produced the lowest amount of ash of any of the pyrolysis processes discussed, compared as a percentage of feed weight. The process was calculated to be economical in the New Jersey area, probably because of the high cost of natural gas, a condition that may not be met elsewhere. The authors stated that there was no air pollution because the gas was being sold, but special precautions may have to be taken at the site where the sold gas would be burned for power production. No tests were run to determine what kind of air pollution was produced by burning the off gasses. No cost estimate was made for treating the scrubbing water but a rough calculation indicated that it would be on the order of $2.00/ton of refuse, compared to a total net cost of $62/ton of refuse for the pyrolysis system. It was calculated that the slagging type of pyrolysis unit would cost approximately 77 percent of refuse incineration.

B. Prepared Discussions

B.1 One of the main points brought out during the prepared discussions was that very little full scale operating data are presently available for the pyrolysis of sewage sludge, refuse, or a combination of the two. Los Angeles-Orange County Joint Authority have a waste pyrolysis unit presently in operation, and Baltimore and San Diego have units under construction. It was asked if the authors of the first paper had any idea what the optimum air ratio was for no Cr^{6+} production and the author indicated that recent tests showed it to be about 40 percent. It was also noted that the rather large amounts of water used during the experiments reported on in the first paper may be responsible for the low levels of toxic concentrations that were found. It was felt that in normal operation the scrubbing water quantities would be far less than were used for the first paper's experiments, giving proportionally higher effluent concentrations.

B.2 The discusser for the second paper pointed out that a pyrolysis project in Seattle that was to produce ammonia via pyrolysis energy was turned down and a waste pyrolysis project in Minneapolis was abandoned by the city fathers after a negative report from consultants. It was also stated that a pyrolysis plant in Baltimore will need $6 to $10 million more to correct air pollution problems due to smaller than expected particles in the gaseous stream. It was felt that quenching water and cooling water blowdown can be serious pollution problems and should be carefully investigated when any pyrolysis tests are performed. The discusser also felt that the second paper predicted fuel values needed for pyrolysis that probably were on the low side, and during later discussion the author indicated this might be true. It was generally agreed that larger scale experiments were necessary, particularly to determine what effects sewage sludge components such as grit and grease might produce.

B.3 There was very little negative comment during the discussion of the third paper but the discusser felt that hydrogen cyanide production might be a problem if it were carried over to the scrubbing water.

C. Floor Discussions

During the floor discussions it was pointed out that the pyrolysis temperature would have a significant effect on whether low molecular weight products were formed, such as gases, or whether there would be a significant amount of high molecular weight products such as oils and tars. It was generally agreed by various floor discussers that pyrolysis probably could treat refuse, or refuse combined with sewage sludge, for less than the cost of incineration. From the papers and from other comments it appears that the total cost of pyrolysis is probably somewhere between 70-80 percent of the cost of incineration. However, it was pointed out that until large scale plants are put into operation, it is impossible to predict total cost from small scale pilot plant work. Low temperature pyrolysis has the advantage of not oxidizing chromium to Cr^{6+} which might leach out of the ash when the ash is used for landfilling. It was generally felt that the water content of both the refuse and the sludge would be important in determining the economics of any pyrolysis unit. Sewage sludge should probably be dewatered to at least 20 percent by mechanical means, with the use of polymers if necessary, in order to minimize the heat loss in heating up the excess water. The grease in sludge may create air pollution problems that are not present in pyrolyzing refuse because they produce an odor, are visible and are not readily water soluble, making their removal difficult. One floor discusser felt that the final paper was probably the most important at the conference, but this reviewer feels that it may be lacking in value due to the fact that no actual experiments on the pyrolysis technique were performed. The calculations were based on data that were given to the authors by manufacturers of the pyrolysis unit. A demonstration project is presently underway in South Charleston, West Virginia. The authors conceded that their calculations would have to be finalized after results were in from the South Charleston demonstration project. One floor discusser felt that it might be possible to create a meld of pure metals if the temperatures were raised in the pure oxygen slagging type of pyrolysis units. This could be an important consideration in simplifying the recovery of metals. There was some concern by various floor discussers as to how much heavy metals remain in the sludge during the slagging process. This type of information was not available because of the absence of experiments.

D. Other Observations and Comments

In general all of the papers for this session were well received. It is a relatively new field of interest and any contributions were felt to be a welcome addition to a rather scarce body of knowledge. The Japanese seem to be very interested in pyrolysis and it is suggested that anyone interested in the field should acquaint himself with Japanese literature. It may be advisable for some of the U.S. project investigators who are working on pyrolysis units to arrange a trip to Japan to observe their experiments and techniques first hand. Many of the details for such a trip can be worked out beforehand by mail and it is felt that it probably would be a worthwhile investment of research funds. It should be pointed out that there was a serious language problem between English-speaking and Japanese-speaking scientists at the conference and any such scientific trip should arrange a translator to assure proper understanding. Although the Japanese made a valiant effort to communicate in English at the conference, overall mutual understanding (from the experiences of this reviewer) ranged from nonexistent to poor.

IV. CRITIQUE OF SESSION

The research reports were well received and it was surprising that the last paper was as well received as it was. There seems to be a serious lack of information on pyrolysis of refuse and sludge so a calculation type of paper with the assumptions that are inherent in such a work usually is viewed skeptically. The first two papers covered a fair range of experiments, from noncombustion and partial combustion pyrolysis of sewage sludge to noncombustion combined sewage and refuse.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Sludge and solid waste disposal is presently one of the major problems confronting the United States. It was rather disappointing to see that the papers dealt primarily with pyrolysis producing excess energy so that the process could be self-sustaining rather than producing a solid or liquid end product that might have a high commercial value. It was generally felt that the solid ash was only useful for fill or aggregate. However, it was significant that the scientists at the conference felt that pyrolysis can probably be accomplished utilizing less net energy than incineration. Pyrolysis does seem to provide a good answer for both sludge and refuse disposal for the large cities that are not near agricultural areas. It is felt by this reviewer and others at the conference that the entire picture of sludge disposal should be approached from the point of view that the sludge contains valuable elements (nitrogen and phosphorus) that may be of use to farmers. Refuse, rather than just being considered for its heat value, should be considered as a source of raw materials such as metals, glass, plastics, etc. Pyrolysis seems to solve a number of sludge disposal problems but it should be realized that the gas scrubbing operations at the end of a pyrolysis unit probably will produce some water pollution that will have to be treated. It is felt that research in the area of pyrolysis should continue, perhaps at a slightly faster pace than is presently underway. It was generally agreed by most of the scientists that this reviewer personally conferred with that one of the major stumbling blocks for many engineers trying to solve waste pollution problems is their failure to realize that "everything has to be somewhere." Essentially, most of the techniques we presently employ for waste treatment force the pollutant to either go through a chemical or phase change or to go to a more concentrated state, where the ultimate disposal might be easier to handle. Looking ahead to the future it is difficult to imagine that we will not eventually be a total reuse society. Perhaps we are at the point now that we should begin thinking along these lines.

I. SESSION

A. Theme of Session: Sludge Thickening

B. Papers Presented: 24. Dissolved-Air Flotation in Activated Sludge.
J. Bratby, G.v.R. Marais (South Africa)

II. REVIEWER

A. Name: Bart T. Lynam

B. Position and Affiliation: General Superintendent
Metropolitan Sanitary District of Greater Chicago
Chicago, Illinois

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 24

The authors in their paper "Dissolved-Air Flotation in Activated Sludge" summarize much of their experimental work and present a design example. They propose that the dissolved-air flotation process is useful for both sludge thickening as well as viable alternative for secondary sedimentation. While the use of dissolved-air flotation for sludge thickening has been well documented, it seems doubtful that it would be a practical alternative to secondary clarification by gravity settling. This is in light of the fact that no data were presented to justify secondary clarification by dissolved-air flotation.

Many theoretical and empirical relationships which would affect the design of a dissolved-air flotation system were presented in the paper. These relationships were based on experimental work conducted by the authors and reported in earlier publications. However, it is difficult to evaluate these relationships presented since the scale of the equipment used to generate the data is not described and the earlier publications cited are of limited circulation. The importance of the size of the units used was pointed out by Ettelt[1] who, in his dissolved-air flotation studies at the Metropolitan Sanitary District of Greater Chicago in the early 1960's, found that the adhesion efficiency (percent of total air supplied attached to solid surfaces) in the laboratory scale equipment was substantially less than in the full scale units. Ettelt attributed the reduction to a lower intimacy of contact between bubbles and solids in the full scale equipment and the higher turbulence caused by the inlet velocities in the full scale units, which tended to shear the gas bubbles from the solid particles. Thus Ettelt found that the inlet design, i.e., reduction in turbulence and increasing the contact time, was the key to the successful operation of the full scale dissolved-air flotation units. Consequently, since the authors emphasized the empirical and theoretical aspects of dissolved-air flotation as opposed to the practical aspects of full scale operation, one must assume that much of their experimental work was done on laboratory-scale equipment.

The authors have chosen not to reference and review the work of others who have published in this area. While the use of dissolved-air flotation is not extensively being used, it is not a new process and there are many who have worked on the process and have made important contributions to this technology, for example, Ettelt.

B. Prepared Discussions

The discusser, Mr. A. Baud (France) brought out some interesting points concerning the paper and the dissolved-air flotation (DAF) process in general. He felt that even though the DAF process was more sophisticated than gravity sedimentation, the DAF process has its advantages in providing a more concentrated thickened sludge (2 to 3 percent for gravity thickening compared to 3 to 5 percent for DAF) at much higher solids loadings.

The main point of disagreement with the authors was in the thickening ability of the DAF process. Mr. Baud had observed DAF units capable of producing a thickened sludge of 4 percent at solids loadings of 100 $kg/m^2/day$, while the pilot plant results of the authors would have predicted a 4 percent sludge at a solids loading of only 40 $kg/m^2/day$. Bratby countered that the observations made by Baud could have been with DAF units which were using polyelectrolytes. In such a case, the polyelectrolytes could have aided the thickening ability of the DAF unit. However, what should have been pointed out was the fact that differences in the sludge characteristics could have accounted for discrepancies in the observations. In fact, Bratby points out in response to a question by Baud concerning whether or not the mathematical model in the paper was universal or not, that the model is limited to the sludge tested and that the influence of sludge characteristics (SVI, size of floc, etc.) on the thickening ability of the DAF was not studied and was one of the limitations of the experimental results.

C. Floor Discussions

There were several questions from the floor which stimulated some interesting discussion concerning the paper by Bratby and Marais. The use of the dissolved air flotation process in place of secondary sedimentation which was suggested by the authors received a considerable amount of discussion. One question concerned the cost comparisons of the DAF and the secondary clarifier and the effluent quality one could obtain from a DAF. Bratby pointed out that the DAF total capital costs were more costly at mixed liquor concentrations of 1000 mg/ℓ and higher. However, the cost comparisons would be even more pessimistic if the operating cost were included which would no doubt be much higher in the DAF unit. This fact coupled with the fact that most activated sludge plants operate in the 2000 to 3000 mg/ℓ range makes the use of the DAF even more questionable.

In spite of the above economic shortcomings of the DAF, Bratby felt that the DAF should be considered since there would be less land required and the sludge would be thicker and thus possibly require much less further dewatering processes. Also, he pointed out that in his studies the effluent quality from the pilot DAF unit which he used produced effluent suspended solids in the range of 6 to 10 mg/ℓ, which is comparable to a secondary clarifier. Nevertheless, this kind of effluent quality needs to be proven on a large scale DAF unit.

Another discusser concurred with Mr. Baud and felt that the results obtained were much poorer than he had observed. In his observations of DAF units in Sweden, he found that at loadings of 100-150 kg/m²/day, a 4-6 percent sludge was obtained. With the use of polyelectrolytes (1 kg/ton), 8 percent sludge was obtained at loadings of 200 kg/m²/day Mr. Bratby commented that the use of intermittent scrapers could have accounted for the differences in his observations and the results Bratby observed. In Bratby's closing statement, he emphasized the fact that the effects of different sludge characteristics on the performance of the DAF were not studied and this was one of the major limitations of the experimental work.

IV. CRITIQUE OF SESSION

The paper on "Dissolved-Air Flotation in Activated Sludge" stimulated some limited discussion and interest. From a practical point of view, much of the presented information had been previously reported over the past 15 years in a progressive manner in various technical publications throughout the world. I cannot judge the report to be highly significant.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

In my opinion much of the paper is existing technology previously reported and does not require new research. Full scale work on dissolved-air flotation is progressing in the United States. The United States Environmental Protection Agency's program of funding under Public Law 92-500 will bring new designs as wastewater treatment plants begin to create activated sludge in order to upgrade present treatment.

REFERENCES

Ettelt, G. A., "Activated Sludge Thickening by Dissolved Air Flotation," *Proc. 19th Annual Purdue Indus. Waste Conf.*, Lafayette, Indiana, May 1964.

I. SESSION

A. Theme of Session: Process Variability in Activated Sludge as Related to Temperature

B. Papers Presented: 27. Variability of Temperature and Other Process Parameters - A Time Series Analysis Sludge Plant Data.
K-C. Lin, G. W. Heinke (Canada)

II. REVIEWER

A. Name: Bart T. Lynam

B. Position and Affiliation: General Superintendent
Metropolitan Sanitary District of Greater Chicago
Chicago, Illinois

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 27

The objective of this paper was to study the variability of activated sludge plant data pertaining to the parameters such as temperature, BOD_5, suspended solids, mixed liquor suspended solids and sludge volume index. This has been attempted by employing harmonic analysis and spectral analysis, the tools available in time series analysis[1].

The basic assumption in application of harmonic analysis is that the time series is made up of sine and cosine waves with different frequencies. More formally we assume that if z_t denotes an observation from time series

$$z_t = \alpha_0 + \sum_{i=1}^{v} [\alpha_i \cos (2\pi f_i t) + \beta_i \sin (2\pi f_i t)] + e_t \qquad (1)$$

where $f_i = i/N$ is the i^{th} harmonic of the fundamental frequency 1/N. e_t is assumed to be independent and normal with zero mean and variance σ^2. This model is tested against

$$z_t = \alpha_0 + e_t \qquad (2)$$

as truly random model. A test for the fit shows if the series contains a systematic sine component having frequency f_i, amplitude A and phase angle F. An estimate of sample spectrum can be obtained from (1).

However, if the stationary time series are characterized by random changes of frequency, amplitude and phase, the sample spectrum fluctuates wildly and is not capable of meaningful interpretation.

The statistical tools employed in this paper are powerful; however, the impact of the conclusions drawn in this paper cannot be validly ascertained.

In our experience, we find that it is desirable to check the assumptions made on the stochastic term in the model as to its probability distribution. The common assumption of normality does not seem to hold for many parameters that are of interest in wastewater research. It is our opinion that the authors have made an excellent effort to obtain the inferences reported in the paper. However, the authors have made little effort in translating the meaning of their conclusions to readers who are not familiar with the terminology of spectral analysis.

At MSDGC, we are interested in employing autoregressive techniques as described in [7]. The basic idea is as follows: Fourier series models approximate continuous functions on $(0,2\pi)$. However, any continuous function can be approximated by polynomials (using Stone-Weirstrass Theorem). If we now add a stochastic component to these approximations, we incorporate randomness into the process. Autoregressive model is a discrete analogue of polynomial function. Thus, it seems that more information can be obtained as to the behavior of any one parameter. Further transfer function models can be fitted to study the relationships that might exist between two parameters.

In the final analysis, the results of the above paper can be only considered as preliminary results, and more work needs to be done before the inferences could be of tangible utility in the study of activated sludge processes.

B & C. Prepared and Floor Discussions

The comments contained in both the floor and formal discussions did not contain any significantly new information regarding statistical treatment of plant data. All present seemed to agree that the statistical treatment used was interesting and could be of value to the sanitary engineering profession.

IV. CRITIQUE OF SESSION

The paper was not received very well due to the special nature of the report. The paper does contain original work on the relationship of the various process parameters. The statistical analysis of the data and the techniques used were impressive and of high quality. The author presented an analysis of a large volume of data which can be readily understood.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The obvious use of temperature in the control of activated sludge processes makes the paper a source for reference to techniques for analysis of data as presented. Additional research is needed in the practical use of data such as temperature in the control of activated sludge plants. However, other parameters may be more readily available as primary control or direct process control.

REFERENCES

[1]Jenkins, G. W. and Watts, D. G., Spectral Analysis and Its Applications, Holden-Day, San Francisco, 1968.

[2]Box, G. E. P. and Jenkins, G. W., Time Series Analysis Forecast and Control, Holden-Day, San Francisco, Revised edition, 1976.

I. SESSION

A. Theme of Session: Aeration Ponds

B. Papers Presented: 30. Comprehensive Temperature Model for Aerated Biological Systems.
Y. Argaman, C. E. Adams, Jr. (USA)

33. The Efficacy of an Equalization Pond in a Water Reclamation System.
B. M. Van Vliet, H. H. S. Wiechers,
O. O. Hart (South Africa)

36. Scale-up Methodology for Surface Aerated Reactors.
N. W. Schmidtke (Canada), I. Horvath (Hungary)

II. REVIEWER

A. Name: Edward S. K. Chian

B. Position and Affiliation: Associate Professor of Environmental Engineering, Department of Civil Engr.
University of Illinois at Urbana-Champaign,
Urbana, Illinois 61801

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 30

The temperature dependence of biological oxidation is very important in considering both the efficiency of aerated lagoon treatment of wastewater and the costs associated with it. Therefore, accurate prediction of temperature of aeration ponds under cold and warm weather conditions is required to determine the substrate removal rates and thus to determine the detention times under cold weather conditions and the subsequent oxygen requirements under warm weather conditions. Considerations were given in Paper No. 30 to all the energy terms associated with the heat balance around a completely-mixed aeration basin, along with a comprehensive review of methods available for predicting heat evolution and dissipation under different process conditions. Confirmation of the temperature model has been carried out on a 12-month basis while operating a full scale aeration basin treatment system. The good agreement between the actually measured and the calculated temperatures indicates the validity of the temperature model as proposed by these authors.

A.2 Paper No. 33

The performance of an equalization pond which was incorporated later in a water reclamation system between the high lime process and the ammonia stripping tower was discussed in this paper. The need for such an aerated pond arises from the poor performance of a current water reclamation system without an equalization basin. In addition to affecting quality equalization, this pond was also found to improve the efficiency of an ammonia stripping tower, to reduce calcium carbonate supersaturation, to provide a microbiological barrier, and to facilitate the downstream control of breakpoint chlorination.

A.3 Paper No. 36

The complexity of industrial waste treatment process design using aeration basins dictates that prototype plant simulation using models in the laboratory be used to minimize risk of process failure. The scale-up of surface aerators was discussed in this paper using three geometrically similar, square aeration tanks to provide data for the development of a scale-up equation based on the postulate that equal mass transfer rates in model and prototype will give equal process results. The postulation of using equal mass transfer coefficients, such as k_La, for scale-up appears to be a better one that that of using equal power input per unit volume, with geometrically similar systems. Therefore, the use of a parameter relating to performance of the system, such as k_La in the case of oxygen transfer, gives a valid approach in scale-up. The apparent weakness of this approach is that the biological similarity between the prototype and the model systems has not been considered in scale-up. This can be circumvented, however, by incorporating the correction term α for k_La based on the average value of α obtained from a number of biologically similar systems.

B. Formal Discussions

B.1 The discusser commented that temperature is only one of the important parameters involved in a biological treatment system. Others such as the nature of the waste materials, pH, ionic strength and dissolved oxygen should all be considered. Only when all of these variables are well defined can a temperature model be developed meaningfully. A number of questions were also raised by the discusser as to the heat gained from a compressor using either air-cooled or water-cooled systems, heat loss in the distribution system employing an air-cooled system, the rate constant of the autocatalytic reaction of the biological system, as well as the correctness of using similar expressions in calculating the cooling effect of mechanical and diffused aeration systems.

B.2 The discusser commented that the concept of incorporating flow equalization in a wastewater treatment system is by no means a new one. Apparently these authors faced a practical problem as described in their presentation. They did it simply for the purpose of solving problems encountered in their wastewater reclamation system. The additional advantages of improved ammonia stripping, reduced calcium carbonate precipitation requirements, and improved microbiological quality may be unexpected benefits of such equalization ponds. This may be why these authors were so excited about the findings of all such additional benefits. The way these authors reduced data of operation in an empirical mathematical model impressed the discusser as being an elegant one. However, the question of the mechanism of removing microorganisms with the equalization pond was raised. Also, the rationale behind the selection of 125 hour residence time was brought out by the discusser.

B.3 The major concern as raised by the discusser was whether the correlation developed for scale-up of an aerator is applicable to geometrically dissimilar systems as well as to prediction of power requirements. The discusser's comment that the paper presents a scale-down instead of a scale-up of the surface aerator appears to be a valid one since most of the practical design involved in predicting power requirements for fermenters of various sizes is based on data available within the size range rather than extrapolating beyond experimental data while using a geometrically similar system.

C. Floor Discussion

The correctness of using the term free energy in energy balance is doubtful. Entropy is a more correct term and should be used. The question on the sensitivity of the heat input terms, such as solar, mechanical and biological, etc. was raised. The opinion of the authors is that the sensitivity is overridden by other parameters such as temperature.

High heat loss through evaporation while using the surface aerator can be overcome by using a diffused air system. Surface aerators should be employed when dealing with a high strength waste. This is especially true under warmer weather conditions. Diffused air systems should be used when treating a dilute waste especially under colder weather conditions. This is due to its lower rate of evaporation.

Since the biological treatment rate constant is also a function of the BOD remaining in the well-mixed reactor according to the Monod's model, it should be considered along with the temperature effect on the rate constant.

The basis for the selection of detention time was an arbitrary one which was somehow related to the diurnal variations in wastewater. The mechanism of pathogen removal was probably due to exposure to high pH for an extended period of contact. However, simple physical adsorption on suspended solids should be explored.

The question of whether the scale-up equation developed on the basis of using a single aerator is applicable to a multiple aerator system was raised. The performance of an aerator in the presence of other aerators surrounding it is indeed affected, since the criterion of geometrical similarity between these systems will no longer hold. A 15 percent reduction in oxygen transfer with the use of a multiple aerator system has been experienced.

Other questions regarding scale-up of power input to the aerator were raised. The relationship between k_La and P/V varies from 0.95 to 0.65 power depending on the size of the system. The smaller power is applicable to a larger system.

IV. CRITIQUE OF SESSION

In view of the amount of literature work involved and the good agreement between the measured and the calculated temperature data observed in a 12-month period with an existing aeration basin, the quality of this paper is excellent. The paper was well received although the apparent lack of originality is shown by the previous work reported by other investigators.

The quality of the equalization pond paper was good in that the plant operation data have been formulated into a mathematical model which can be transferred to study other cases. The originality of incorporating an equalization pond in a wastewater treatment system is, however, not there. The mechanism of pathogen removal as proposed by the authors should be substantiated in the laboratory using the same microbial flora as indicator microorganisms.

Although the quality of the scale-up research was good, it was not too well received from the floor. There were controversies on the question of geometric similarity, relationship of P/V to k_La of different sizes of aeration basins as well as the use of multiple aerators and other matters. While the overall originality of the paper was not evident, the paper does provide certain originality in relating k_La/N (where N is revolutions of the impeller per unit time) to Fronde number as well as k_La to N and Di (impeller diameter).

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Since most parts of the United States are located at latitudes that have four distinct seasons, adequate temperature projections would alleviate failure of biological treatment systems to achieve design discharge goals or gross overdesign. This paper is therefore pertinent to the U.S. needs in solving design problems associated with aeration basins.

In view of the trend in reclaiming wastewater in arid regions of the United States, the advantages of incorporating a surface aerated equalization pond should be of value to us.

While extensive work has been done in defining power characteristics of mixing impellers in a fermenter type aerating system, a paucity of information is available in the literature concerning oxygen transfer and agitator geometry relations as applied to surface aeration systems commonly employed in wastewater treatment. The paper dealing with scale-up of aerators is pertinent to U.S. needs in solving problems regarding design of surface aerators.

I. SESSION

A. Theme of Session: Advanced Waste Treatment and Physicochemical Treatment of Wastewaters

B. Papers Presented:

37. Investigations into the Lime Precipitation of Raw Municipal Wastewater.
D. Jenkins, F. M. Lee (USA)

40. Calcium Carbonate and Magnesium Hydroxide Solubility Product Values for Heterogenous Systems.
H. N. S. Wiechers (South Africa)

43. Advanced Wastewater Treatment by Chemical Precipitation with Lime and Ammonia Stripping in Ponds.
E. Idelovitch, T. Ruth, M. Michail (Israel)

46. Improvement of Tertiary Filtration Efficiency by Upgrading Biological Activity.
G. M. Faup, J. L. Bebin, J. C. Jacquart (France)

II. REVIEWER

Name: Walter J. Weber, Jr.

Position and Affiliation: Professor of Environmental and Water Resources Engineering and Chairman of the Water Resources Program
The University of Michigan
Ann Arbor, Michigan

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 37

The paper was concerned with laboratory jar tests and a pilot plant study, in a two gallon per minute continuous flow system, using sewages of different strength and with normal diurnal flow variations. The object of the study was to assess the capabilities of this process and to provide data which might help to reduce costs and improve the efficiency of primary treatment.

Nine suspensions were prepared by adding powdered quicklime to a container in which vigorous mixing kept the lime in suspension. The lime was added at 360 mg $Ca(OH)_2/\ell$, sufficient to maintain a pH of 11 in the clarified effluent. The pilot plant had four compartments, in each of which the nominal residence time was six minutes. The paddle speeds produced velocity gradients (referred to as "G") measured in $seconds^{-1}$. These gradients varied from 15 to 100 sec^{-1}. One particularly interesting aspect of this study concerned the nature of organic compounds which are removed by lime treatment. The organics measured in solution were those that remained after filtration. These organics and those in suspension were examined by gel-chromatography in order to determine molecular weight distribution.

The essential findings of the study may be summarized as follows: 1) optimum removal of suspended solids and COD by lime treatment of sewage is obtained at "G" values of 30 sec^{-1} but it is not critical if this value is exceeded; 2) the critical conditions involved in the removal of suspended solids, COD and phosphate from sewage by lime treatment could be achieved in 12 min at "G" values of 60 sec^{-1}; 3) high concentrations of lime when added to sewage take longer to dissolve than lower concentrations; 4) calcium carbonate formation on dissolving lime particles is thought to be more effective in preventing lime dissolution than magnesium hydroxide formation; 5) lime dissolved in recycled effluent gave better results than lime first dissolved in water; 6) the distribution of molecular weights of the organic components in sewage remained unchanged after liming; 7) the distribution of low molecular weight organic components was the same after lime treatment as before; and, finally, 8) lime treatment is not effective in removing low molecular weight substances.

A.2 Paper No. 40

Dr. Wiechers reported studies at Pretoria, South Africa, which he indicated were designed to determine "solubility products" for calcium carbonate and magnesium hydroxide in "stable" lime-treated and recarbonated secondary effluents. The "solubility products" were correlated with the characteristics of the wastewater effluents by empirical models.

Further, degrees of supersaturation for $CaCO_3$ and $Mg(OH)_2$ were determined for the effluents from various unit processes of a wastewater reclamation plant. Wiechers reported that when predictions for these numbers (degrees of saturation) were based on the solubility products determined in his studies, they agreed more with actual findings than when such predictions were based on conventional thermodynamic solubility products.

The author indicated that the solubility products determined experimentally agreed closely with literature values for lime-treated raw sewage and other heterogeneous wastes and claimed therefore that their application is not limited to secondary effluents. He further stated that these solubility products enabled more realistic, yet general, calculations of $CaCO_3$ and $Mg(OH)_2$ precipitation in lime treatment of wastewater, and determination of the stability of effluents produced by lime treatment, than do conventional thermodynamic solubility products.

A.3 Paper No. 43

This paper dealt with the wastewater treatment scheme of the first stage of the Dan region reclamation project in Israel. The project provides for advanced treatment of wastewater from the Tel Aviv metropolitan area and indirect reuse of effluent by ground water recharge. The advanced treatment consists of chemical precipitation by high lime, with magnesium flocculation, filtration, and detention of the lime treated effluent in polishing ponds, mainly for the purposes of free ammonia stripping. Stabilization by CO_2 is carried out before ground water recharge. The lime sludge is conveyed to sludge drying beds before final disposal. The basic operational parameters which are considered in the paper follow. The pH in the secondary effluent ranged between 8 and 8.8, and was raised by high lime treatment to values of about 11.5. Because of variations in the sludge blanket clarifier operations, they were varied between roughly 11 and 12, but averaged 11.5. The studies indicated that the optimum pH should be between 11.2 and 11.5. Magnesium concentrations varied between 20 and 40 mg/ℓ. This was not enough for optimum flocculation and had to be supplemented by addition of magnesium chloride to a level of about 45 mg/ℓ in magnesium. The lime dosage required, because of the high alkalinity of the water, was about 700 mg/ℓ. An interesting observation was made on the effect of the polishing pond on continuing precipitation of the phosphorus. By high lime, phosphorus was reduced to about 0.5 to 2 mg/ℓ whereas after the polishing pond the concentration was always below 0.4, the average being 0.3 mg/ℓ. Ammonia stripping is the main process of the polishing pond with a detention time of 9 days. Some ammonia is also removed during lime treatment, but the main part of the ammonia is removed by stripping during detention of the effluent in the polishing pond. The pH is also reduced in the polishing pond from roughly 11.5 to values which averaged 10 to 10.5, sometimes lower. Nitrification must be avoided in the process since no provision is made for nitrate removal. In summary of plant performance, virtually complete destruction of coliforms was achieved along with about 96 percent phosphate removal, 90 percent suspended solids removal, 82 percent ammonia removal, 80 percent BOD reduction, 74 percent Kjeldahl nitrogen reduction, and 72 percent removal of COD. The authors claim that the effluent is suitable for direct agricultural, industrial, and non-potable municipal reuse as well as for ground water recharge.

A.4 Paper No. 46

This paper described the results of studies of the effect of biological growths and preaeration on the performance of sand filters used for tertiary wastewater treatment. It further described the results of an evaluation of an alternate filtration media for such applications, specifically, extruded expanded clay.

With respect to preaeration ahead of sand filters, the authors concluded that this practice 1) slightly improves suspended solids removal (64 percent versus 57 percent); 2) marginally increases removal of dissolved material (expressed as COD, 11 percent versus 8 percent); and 3) does not result in any measurable increase in retention of suspended solids in the filter.

The authors claim that expanded clay, without preaeration, gives better suspended solids removal than sand, but no measurably greater removal of dissolved organic matter. With preaeration, and a flow velocity of

10 m/hr, soluble COD removal with expanded clay increases to approximately 30 percent, compared to about 10 percent removal with sand, with or without preaeration, and to expanded clay without preaeration. Removal of suspended solids by expanded clay with preaeration increases to approximately 85 percent.

For a given head loss, the authors report expanded clay yields a higher suspended solids retention than sand and this is increased further by preaeration. The authors attribute the improved operation with expanded clay, and with preaeration, to enhanced biological growth on the filters. They further suggest that above some critical flow velocity (or below some minimal detention time) the effects of biological activity become negligible; an experimental flow velocity of 20 m/hr used in the pilot studies described by the authors clearly yields results inferior to those obtained with a flow velocity of 10 m/hr in a filter of 1.5 m depth.

B. Prepared Discussions

B.1 Van Vuuren (South Africa) emphasized that the results of this paper (No. 37) very clearly illustrate the superior performance achieved when lime is added to a recycling stream as compared to direct lime addition. He substantiated some of these findings by referring to experiences in South Africa. In mixing a lime slurry of $25\ g/\ell$ with secondary effluent they have considered it necessary to provide for a reaction stage into which sludge from the clarifier is recycled. This provides crystal seeding and reaction times required during low temperatures. The dilution effect on the lime slurry is thereby automatically provided for. He cited evidence from pilot scale studies that solubilization of solid organic substances by lime occurs and prolonged sludge retention in the clarifier should be avoided to avoid increases in soluble COD. Further, he stated that the clarification process is highly dependent on the concentration level of magnesium in the raw effluent. When deficient in magnesium, ferric chloride addition is required. Finally, he stated that he thought that the conclusions drawn by the authors that hydrolysis of high molecular weight organic materials in solution does not play an important role is a very important statement. He asked whether the authors had observed if solid organic substances can be hydrolyzed by high lime treatment.

B.2 Mr. Parker (Australia) noted that the problem of achieving a stable effluent after lime precipitation and recarbonation is of importance not only in phosphorus removal from wastewaters but also in water treatment plants in which the lime-soda ash softening process is used. He indicated that the lime dosage required to remove phosphorus from domestic sewage is primarily dependent on wastewater alkalinity and not the phosphorus concentration *per se*, and agreed that an understanding of the equilibrium and reaction kinetics of the lime precipitation process is essential if the chemical stability of effluents and the calcium dosage to achieve such stability is to be more effectively controlled. Parker noted that calcium carbonate solubility products for lime-treated sewage have been reported elsewhere to be a function of waste strength but that in the present paper Wiechers has indicated general applicability to other heterogeneous effluents. He called for some comment by the author on the validity of extrapolating these solubility products and correlations, particularly to high strength domestic sewages with appreciable industrial loads where the ion-pairing effects with anions other than bicarbonate, hydroxyl and sulfate may be of importance.

Regarding observations of increased calcium carbonate solubility in heterogeneous systems relative to pure systems, Parker noted that, in addition to the author's suggestion of ion-pairing effects and inhibition of calcium carbonate crystallization by very low concentrations of phosphates, Wiechers also indicated that calcium complexation with dissolved organic matter may offer an explanation for this observation. In this regard, he indicated it would be of interest to hear if any attempt was made to correlate calcium carbonate solubility products with COD and, in light of the previous paper (Jenkins and Lee), with magnesium concentration. He noted that an objective of the author's study was to establish what constitutes a stable water after precipitation and that in the past the Langlier stability index and the method of Caldwell and Lawrence have been used to assist in determination of the chemical stability of lime-treated and recarbonated effluents from the lime-soda ash softening process. These methods require calcium, alkalinity, pH, temperature and ionic strength data to determine effluent stability. Wiechers, Parker commented, claims that solubility data, with allowance for some ion-pairing effects, can be used to predict chemical stability of effluents. Parker noted that since the practical effectiveness of any stability criterion is indicated by improved control of the precipitation and recarbonation processes, it would be of interest for the author to comment on any actual plant data indicating improved effluent stability by utilization of the solubility product values and correlations determined in this study.

8.3 Wachs (Israel) commented that, although the title of the paper describes lime treatment as chemical precipitation, when the pH is raised by the addition of lime to pH values reaching 11 and 12, other processes take place besides precipitation. One of these processes is the breakdown of high molecular weight organic molecules into molecules of smaller molecular weight. He showed a slide of some work at the Technion showing percentages of different fractions of organic matter, in terms of molecular weight, corresponding to before lime treatment and after lime treatment.

He indicated that these data suggested that the biodegradability of organic matter remaining in solution after lime treatment will be substantially increased by the treatment, and that one would therefore expect increased biological activity on the surface of the sand into which such waters are injected. This could cause fouling and plugging of the aquifer due to increased biological activity although the TOC of the injected water should be improved (reduced). Further, he noted that ground water recharge applications must take careful consideration of the stability of the effluent with respect to calcium and phosphorus. Unless this stability is insured, the precipitation of calcium deposits in the aquifer may cause a gradual decrease in the aquifer capacity. He indicated that the results presented in the paper had been obtained during a summer season and that, because temperature affects several of the processes occurring in the system, it would be of interest to supplement this information with data obtained during winter operation.

B.4 Eckenfelder (U.S.). Filtration following biological treatment has traditionally been for the purpose of removal of suspended solids and the BOD associated with these solids. The work of this paper and of other reports that have appeared recently would indicate that with proper design and operation of the filter, substantial soluble BOD and associated COD can also be removed. Work reported recently by the Tokyo Metropolitan Government indicates that using either upflow sand filters or mixed media downflow filters at hydraulic loadings between 5 and 20 meters per hour, tertiary filtration can achieve COD removals of 75 percent or a reduction of the filter influent COD from 8-16 mg/ℓ to 3-6 mg/ℓ, and associated COD removals of 10-20 percent. The work reported in this paper has indicated that expanded clay media has a substantially higher specific surface and that soluble COD removals in the order of 30 percent have been achieved using preaeration to provide sufficient dissolved oxygen for biological activity. It is difficult to compare the Japanese results directly with those described in this paper because of rather different influent concentrations to the filter. It would appear that post-filtration with preaeration is a feasible process where the BOD in the feed to the filter is something on the order of 20 mg/ℓ or less. Studies in the United States (Jeris *et al.*) using an upflow expanded bed sand filter have achieved up to 85-90 percent BOD reduction from domestic wastewater with retention periods on the order of 8 minutes. In these studies, sand from the top of the filter is continuously removed and passed through a screen to separate the biomass from the sand and the sand is then returned to the filter. Jeris' data do not correspond directly to the data reported in this paper. Because of higher influent BOD, on the order of 50 mg/ℓ, either an aerated recycle has to be employed or pure oxygen introduced. Eckenfelder asked the authors what their experiences had been when the filter is used not as a filtration device alone but also as a biological oxidation unit, relative to potential difficulties due to buildup of biological solids in the filter, corresponding backwash frequency, and oxygen limitation in the filter with respect to maintaining aerobic activity and high efficiency of removal.

C. Floor Discussions

C.1 Paper No. 37

Kingsford (NZ). Lime treatment is becoming popular for phosphorus stripping from effluents and it has been suggested that magnesium is necessary for this purpose and that successful demonstrations have been, at least in part, consequences of magnesium impurity in the lime. Perhaps the principal function of the lime is to raise the pH and provide for magnesium precipitation.

Wiechers (South Africa). Reported studies in South Africa, in which they have also had a look at the kinetic aspects of this process, not only at lime dissolution but also of calcium carbonate and magnesium hydroxide precipitation, have found that the limiting reactions are the lime dissolution reactions. Commented that the inhibition of lime dissolution by calcium carbonate and magnesium hydroxide may not be as bad as indicated in the paper. The kinetics were studied by observing a change in hydroxide concentration. In a pure system, this technique is valid. However, when one adds lime to a heterogeneous system, such as sewage or one containing magnesium or other alkalinity such as bicarbonates, the hydroxide will react with the bicarbonates, the phosphates, the magnesium, and some of the hydroxide will be removed with time. In other words, a study of (OH^-) with time is an indication of the net effect of lime dissolution and therefore the observations made and the kinetic model are an indication of the net effect.

Molof (USA). Indicated two points in the paper that he thought deserved discussion. First, in the addition of any coagulant, the resulting sludge is really a major consideration. Too often emphasis is placed on the liquid clarity but not on the sludge handling characteristics. Second, he questioned why the authors had chosen a pH of 11 to study. Indicated that there was evidence that between pH 11 and 11.5 one starts to get more rapid magnusium precipitation which would change the sludge characteristics. Also questioned use of the term "high lime," indicating that he wouldn't classify the pH of 11 as high lime.

Dunning (NZ). Indicated two questions of interest to him. First, whether the authors had any problems in their experiments in simulating diurnal flow. Secondly, relative to potential applications in coastal areas, for coments on the use of lime for raising pH in combination with sea water, utilizing the magnesium as the flocculating agent.

Reply - Dr. S. Jenkins, who presented the paper in the absence of his son, Dr. D. Jenkins, indicated that several important points were raised, particularly by Dr. Weichers, on the kinetics of lime dissolution and the kinetics of lime precipitation in particular. He suggested it would be far better to have authoritative answer from the authors appear in the proceedings. He did indicate one or two matters that he might be able to deal with, as rather a bonus to the audience, because of particular concern with processes of this kind in the United Kingdom. At a conference to take place in Johannesburg, South Africa, in June 1977, which will be directed especially to chemical/physical approaches to wastewater treatment and reclamation of water, an opportunity will be given for a description of the facilities that are available in the United Kingdom under the Department of the Environment. There are excellent facilities for carrying out work on chemical/physical and also on biological treatment of sewage at a large center at Coldhill, near Birmingham, United Kingdom, as a part of a study by the NATO countries, and especially the committee known as the CCMS Committee (Committee on Challenges in Modern Society). The Department of the Environment also has work that is being carried out on a smaller scale at Manchester, where a very highly industrial sewage is being treated by a variety of chemical/physical processes in combination with biological treatment. The importance of magnesium in lime coagulation and the fate of organic substances are points that have been raised by several speakers. It may be remembered that a process was developed some years ago for the electrolytic treatment of sewage diluted with sea water, and one of the features of the electrolytic process was to produce a pH sufficiently high to force the flocculation of magnesium and the organic substances that are present in the sewage. Mr. Van Vuuren referred to the possibility of the solubilization of suspended matter. Jenkins expressed the opinion that he feels this is not an important factor in the flocculation of sewage solids, sewage suspended matter, by lime, if one assumes that the fate of any such solubilized material would be the same as original organic substances present. The point that Professor Molof raised concerning the characteristics of the sludge is an important one, perhaps even a critical one. The effect of using lime as a flocculant is to increase the yield of sludge by a factor of 25-50 percent at least. Usually it is found that the solids content of the sludge obtained, under these conditions, also increases so that there is what might be regarded as a compensating advantage of having a larger yield of sludge but a sludge having a higher dry solid content. Nevertheless, Jenkins agreed with Professor Molof that in any complete study of flocculation, it is necessary to take into account the yield of sludge, the quality of sludge and its dewaterability.

C.2 Paper No. 40

Stumm (Switzerland). Objected strongly to the terminology used in this paper on basis he did not think Wiechers had equilibria in any of these systems, nor even pseudoequilibria. For determination of a solubility product equilibrium should be attained from precipitation as well as from dissolution data. The fact that Wiechers waited 24 hours is not sufficient from a point of view of attainment of equilibrium. Furthermore, Stumm commented, the solid phase or precipitate should have been identified; was it an amorphous magnesium hydroxide, a calcite, a magnesium calcite, etc. Weichers had discussed complexation solubilization of calcium carbonates and magnesium hydroxide by organic matter in sewage. Stumm indicated it was his opinion that organic matter in sewage would not form complexes with calcium and magnesium to any significant extent in these instances. Stumm suggested that the study actually dealt with a kinetic phenomenon and, although kinetics are very important from a point of view of practice, the data should not be interpreted in terms of "new solubility products." Stumm recommended that detailed kinetics studies on the nucleation and crystal growth of calcium carbonate and magnesium hydroxide in such systems should be carried out.

Bristow (Australia). Asked the author to explain the effects of ionic strength on the solubility determinations he carried out.

Piatell (Australia). Indicated some factors that he thought should be taken into consideration and which might affect Wiechers' solubility determinations. He noted that the reactions were carried out for 24 hours in air-tight containers which were constantly shaken and that there would likely be gaseous environments above the liquid phase which were somewhat different from an air environment. Further, the pH was not actually measured in the solution while it was in the sealed container but after the solution had been filtered. He questioned the potential effect of aeration and CO_2 adsorption or release during filtration upon the final solubility determinations. He also suggested that the potential buffering capacities of organic acid radicals was not properly accounted for in the approach used by Weichers (calculating carbonate levels from measurements of pH and alkalinity), and asked whether Weichers would consider the determination of inorganic carbon by a total carbon analyzer to be a more realistic measure of total carbonate species concentration.

Zoltec (USA). Questioned the use of Equation 12, Wiechers definition of degree of supersaturation, suggested that he might consider taking the nth root of that equation, where n is the number of molecules in the crystal. As an example, he indicated that determining the degree of supersaturation in this way to yield a number of 3 for calcium carbonate would mean that you would have 3 times as much calcium and carbonate as you would need, as predicted by equilibrium, whereas the number obtained by the present equation would be 9. He suggested that this might be a bit more intuitively meaningful. He also had some questions on Figures 1-3; percent scatter for Figure 1 was listed as 1.12 percent, for Figure 3 as 1.9 percent, and for Figure 5 as 2.05 percent. Zoltec indicated he would think that the fit on Figure 1 is much poorer than the other two and asked for clarification.

Weber (USA). Underscored what Stumm said about the substantial difference between the kinetics phenomena apparently observed by Wiechers and his interpretation of the data in terms of thermodynamic equilibrium values. Weber suggested that in the 24 hour reaction time utilized, it would be unlikely for thermodynamic equilibrium to be achieved. Weber commented that he agreed that the organics in wastewater would not be likely to form significant soluble complexes with calcium and magnesium in that the coordination capacity of calcium and magnesium for the types of organics that would be typical of wastewaters would not be very strong. However, he noted there is another consideration that relates very importantly to the fact that the solubility numbers determined by Wiechers were not thermodynamic equilibrium values but rather kinetic intermediate values; this consideration is that the types of organics that are present in wastewaters will very definitely adsorb on precipitating nuclei and markedly change the rate at which equilibrium is approached. This would very definitely affect the non-equilibrium solubility numbers.

Reply - Wiechers indicated that the work he did, as stated, was only for one effluent but Merrill and Jordan reported a summary of literature values for different effluents from which it was clear that as waste strength increases the "solubility" products for these systems, determined after some specified time, become greater and greater. The second point raised by Parker was that of ion pairing effects. Wiechers agreed that when studying this sort of effluent, when lime treated, ion pairing effects are of consequence. Parker asked about correlations of the pK values with COD and magnesium and in fact this was attempted. No significant correlation could be found for these low COD effluents (20-40 ppm). Regarding stability calculations using the Langlier saturation index, and the Caldwell and Lawrence diagram, these diagrams are indeed not totally adequate in explaining heterogeneous systems. Wiechers agreed with Stumm and Weber regarding the use of the term "solubility product." He suggested that the values he determined are in fact quasi-equilibrium values, not solubility products but perhaps activity products for the specific systems. On the question of organic matter complexing with calcium and magnesium

Wiechers pointed out that this was only speculation and, as indicated in the paper, this could not have accounted for the discrepancy between calcite solubility constants and the actual values measured. Firstly, the total organic matter concentration in the effluent was very low and of this only about one-fifth is in a form which could possibly form complexes with calcium. Adsorption of organics on precipitating nuclei and reduction of rates of precipitation may have had an effect however, as noted by Weber. Bristow asked about the effects of ionic strength. Ionic strength will play an important role in determining true activity products and it would be important to consider these ionic effects for brackish wastes or other wastes of high salt content. Wiechers stated that an attempt was made in the studies to minimize the effects referred to by Platell, first, in the bottle itself by having as little air as possible and filling it to the top; secondly, by doing the filtration as quickly as possible and into a vacuum flask so that exposure to the air was minimized. Relative to the question on the reliability of the determination of carbonic or carbonate ion concentration by means of pH and alkalinity calculations, the techniques used at present for total organic carbon and total carbon are suitable for more precise determinations but, according to Wiechers, they were not available when he did his work and so he used the procedure he did realizing that it was subject to some error. Again in the time required to reach equilibrium Wiechers commented that after the paper was written he had a look at longer equilibration times ranging from 24 to 48 hours and, in one case, on the order of 200 to 250 hours. He found that time does play a role - there is a slight improvement in the pK values of the order of 0.1 or 0.2 of a unit, but that this still did not bring the pK values into the range of those predicted by the true solubility constants.

C.3 Paper No. 43

Marks (Australia). Regarding the lime required to reduce phosphorus to less than 1 mg/ℓ, some research has indicated a dose of approximately twice the alkalinity or, in this instance, approximately 800 mg/ℓ; other research has indicated levels of 200-400 mg/ℓ, directed primarily at achieving a pH of 11.5-12.5, and magnesium hydroxide flocculation. Some researchers have reported lime clarified sewage sludge volumes of 2 to 3 times that of biological sludges. This introduces a major disposal problem. The figures in the original paper for total solids reduction through the clarifier, coupled with lime dose, indicate a sludge production of about 0.5 kg of dry solids per cubic meter of plant throughput, indicating a sludge volume of 3-5 percent of plant throughput. What in fact was the average sludge production? The paper indicates that natural recarbonation reduces the pH in the polishing pond from about 11.5 to 10.5 in 9 days. Other researchers have indicated that it takes 20-30 days, in moderate climates, to achieve a reduction from pH 11.5 to about 8 to 9, normally required for discharge. Finally, there are some indications that the calcium phosphate in lime sludges does not redissolve to any great extent, even when the supernatant is recarbonated to neutral pH. Has any of the work in Israel shown this to be so?

Wechsler (Australia). The water used for ground water recharge eventually will be used for domestic supply. It is disturbing that there is the possibility that refractory soluble organics may pass through the system, and may eventually appear in the drinking water supply. Also, there will eventually be a salt buildup beyond which the water cannot be used for domestic consumption. Wechsler claimed that it is not possible, by analysis, to show that refractory organics do not exist and that one must design around this problem. He indicated his thought that a plant which maximizes the number of different processes for pollutant removal is one which is going to give the widest cross section of removal and that perhaps some process, such as reverse osmosis or activated carbon filtration, should be used when this water is withdrawn from ground water for domestic consumption.

Bristow (Australia). Asked whether the authors had experienced any algae problems in the stabilization pond and whether they have any comment on algal growth control by the high pH. Also indicated surprise at the pH level at which the water was discharged into the aquifer.

Uhlman (West Germany). Asked whether the retention time of the oxidation pond was selected on the basis of maximum BOD removal or maximum suspended solids removal.

Shuval (Israel). Commented on the quality aspects of the reuse water; indicated some might question whether such a high quality effluent is necessary for agricultural reuse. Supported objective of aiming for such high quality for agricultural reuse. High microbiological quality will allow for unrestricted agricultural reuse. If there are pathogens in the water, must restrict the type of crop. High microbiological quality is necessary for the health of agricultural workers and residents of the vicinity of application. High lime treatment does partially remove heavy metals. The avoidance of heavy metals in the soils or possibly in the agricultural products is a worthy goal, particularly in dealing with a wastewater stream from a community of a million and a half people where it would be difficult to control all industrial sources; also know that many heavy metals enter the systems from domestic sources. As to the possible ultimate use of such a water for domestic purposes, Shuval indicated that preliminary tests he has carried out indicate that TOC's as high as 10 can be detected in the recharged ground water; it is obvious that such water would require additional treatment before it could be even considered for drinking water purposes.

Reply - Regarding Wach's question about the distribution of suspended solids, in the observation ponds essentially all the suspended solids are organic. However, in the clarifier effluent as well as in the tertiary effluent some of the suspended solids are calcium carbonates. Regarding the possible clogging of the aquifer, the plans of this project are to add CO_2 for stabilization purposes at the end of the last polishing pond. The amount of carbon dioxide required here is estimated to be about 50 mg/ℓ instead of about 200 mg/ℓ if the carbon dioxide were added directly to the clarified effluent, resulting in a savings of approximately 75 percent in the amount of carbon dioxide required for recarbonation. As for the question on winter results, the processes incorporated in this scheme are greatly affected by temperature. He indicated that since the paper was written they have studied the pilot plant in winter conditions. There are some marked differences between the summer and winter results (he did not elaborate further). Regarding the lime dose required to reduce phosphate, the alkalinity was about 330-400 mg/ℓ as calcium carbonate and the lime dose was about 700-750 mg/ℓ, thus, a lime requirement of roughly twice the alkalinity. As for the use of polyelectrolytes in conjunction with lime, there is no reason why polyelectrolytes should reduce the lime dosage since the lime dosage is mainly dependent on alkalinity and on the pH required. However, they did try polyelectrolytes to improve performance of the plant and effluent quality. Tested about 10-12 different polyelectrolytes but none were found to have any measurable effect. Conversely, when magnesium chloride was added, even in very small amounts (5-10 mg/ℓ), there was a considerable improvement in clarification. Therefore, prefer to use magnesium chloride rather than polyelectrolytes. Sludge is definitely a problem. In this type of operation, except for recalcining for lime recovery, there is no other use that has been found for the sludge. Sludge yields approach about 1 kg dry solids per cubic meter treated. However, one advantage is that the sludge is much thicker than biological sludges, about 8-12 percent solids. Thus, no thickening is required and the sludge can be directly disposed of to drying beds for dewatering. Regarding regrowth of algae in the polishing pond, this was experienced only once, when the detention time was long (14 days). The pH dropped to about 9.5. This is now avoided by having a detention time of about 9 to 10 days. On the question of refractory organics and the suitability of this effluent for domestic reuse, he reiterated that the effluent is meant for ground water recharge only. There are possibilities of using this effluent, mixed with ground water, after it is pumped from the aquifer, for domestic supply but only after treatment with additional water treatment processes such as activated carbon and/or reverse osmosis. The exact process requirements can be determined only after more information about the quality of the recharged ground water is obtained.

C.4 Paper No. 46

Thorton (NZ). Indicated that in preliminary investigations on the use of activated carbon for tertiary treatment they have found that inoculation of the activated carbon filter with bacteria under aerated conditions increased removal of soluble pollutants over that obtained with non-inoculated systems.

Rincke (Germany). Reported observations that chlorination reduced the efficiency of rapid sand filters and that preaeration had positive effects on removals obtained. Indicated that he did not understand why there was such a low oxygen demand in the filter, however. Only 1 mg of oxygen was reported to be needed for 10 mg of BOD eliminated but this should be confirmed by including a measurement of the BOD of the accumulated solids removed by backwashing the filters. Indicated it would also be of interest to know whether any nitrification took place; this could be determined from a nitrogen balance between the influent and effluent. The authors commented elimination of suspended solids in the filter was better when the biological pretreatment was lightly loaded than when the pretreatment was heavily loaded. It is reasonable that the effluent of a highly loaded pretreatment contained more biodegradable material which promoted intensive growth of bacteria in the filter. Thus, the suspended particles in the filter effluent may have been largely comprised of biomass generated on the filter.

Benedek (Canada). Questioned the physical arrangement relative to air entrapment in the filter; asked how this problem was avoided in the downflow filter used. Asked also whether air scour was used in backwashing the filters to remove residue.

Weber (USA). Referred to studies (Weber *et al.*) reported approximately 10 years ago describing the substantial growth of bacteria on activated carbon in waste treatment applications. Noted Thornton's comments that he had observed improved removals by activated carbon systems when the columns were inoculated with bacteria. The significant point is that bacteria will grow on any fine grained media and the objective in developing a treatment scheme should be to provide optimum conditions for this to occur. First, the consideration of the type of reactor is highly important. Weber indicated that there are many advantages that accrue with an expanded-bed type of reactor system and referred to the results he presented on "Biologically Extended Physicochemical Treatment" at the 1972 IAWPR Conference in Israel and earlier papers comparing expanded-bed and packed-bed reactors. Indicated that the expanded-bed reactor was the type of system adopted by Jeris in the recent work referred to by Eckenfelder. The second primary consideration for optimization of this type of treatment scheme, Weber indicated, is the media on which the biological growth is developed. He maintained that just as expanded clay was found in the present investigations to be superior to sand, his results give indications that activated carbon has marked advantages over any other type of media. He cited a number of reasons for this. First, activated carbon has a high affinity for molecular oxygen and, consequently, provides a driving force across the biological film to bring the oxygen more actively into the biofilm. Second, the principal partitioning factor, or driving force, in a system in which sand or expanded clay is utilized is the free energy for biosorption which is relatively low. In a system in which the support medium is material such as activated carbon, the partitioning factor is that of adsorption which has a substantially higher free energy. Therefore, the sharpness of separation in the latter reactor is much higher. The retention time then of the organics is controlled by the retention time of the solid support media rather than the retention time of the fluid media, a highly significant factor. Third, there are, as has been pointed out in a number of discussions at this meeting, a broad spectrum of organic materials which are not readily biodegradable, such as chlorinated hydrocarbons, but which present very real problems with respect to reutilization of wastewater. With activated carbon as a support media, the dual function of adsorption of these materials from solution and retention in the solid phase can be accomplished. One further point - there is a potential advantage in some cases to allowing the system to go marginally anaerobic rather than to try to meet the total oxygen requirements for aerobic oxidation. One of the advantages is the generation of a lesser amount of biological solids. One of the difficulties in such a system is that sulfates can be reduced to sufides and cause some deterioration of effluent quality. This, however, can be controlled by the admission of nitrate in the influent. The nitrate functions as an alternative electron acceptor to the sulfate, producing nitrogen gas instead of sulfides. The performance of such a system is often dependent upon controlling the accumulation of biological solids and, in answer to the question raised by Professor Benedek of Canada, Weber indicated that he had found that periodic air scouring is essential to the maintenance of a thin, active biological film.

Reply - Several questions were raised regarding accumulation of solids in the filter, backwashing and minimum oxygen concentration necessary in the filter. The frequence of washing is a function of the quality of the secondary effluent being treated on one hand and, on the other, the acceptable headloss across the filter. After a physical/chemical process, for example coagulation with lime, on domestic waters, the frequency of washing would be about every 24 hours with a permissible headloss of 1 m. There is a purification plant which has been operating on this principle in France for 3 years with excellent results both in terms of chemical/physical treatment and filtration with expanded clay. The question of the minimum concentration of oxygen to be maintained in the filter is quite difficult; indicated that his work suggested a minimum concentration of 0.5 mg/ℓ. Regarding Mr. Rincke's question about the quantity of oxygen provided relative to BOD and COD in a tertiary filtration plant or after physical/chemical treatment, Faup indicated that he observed that qualities of oxygen consumed were relatively low in relation to quantities of BOD eliminated but could not really explain this. Regarding Dr. Benedek's question on physical arrangement, several techniques can be considered. Aeration can take place either above the filter or in an independent basin. Indicated that he has never observed any problems with air binding of the filter. Regarding the use of expanded beds with activated carbon, Faup commented that there is the cost of the granular media which must be considered and a question of the control of dissolved oxygen in the air expanded-bed system. Suggested that oxygen input to a downflow filter is not limited by expansion of the filter media but that when working with an expanded-bed it may be more difficult to put in exactly the right quantity of oxygen because of expansion of the filter. Also asked whether there is a problem of higher suspended solids concentration in the effluent from an expanded-bed filter than in that from a conventional downflow filter. Faup asked if it would be possible for Weber to comment further on these aspects.

Weber. Three questions were raised by Mr. Faup: 1) relative cost, 2) control of dissolved oxygen addition to an expanded bed, and 3) control of suspended solids in the effluent from an expanded bed. Regarding first the question of cost, one has to look at functionality and the cost effective utilization of a material. Activated carbon serves at least two functions, whereas sand and, to a large extent, expanded clay serve only one function. Activated carbon provides for adsorptive removal of biologically resistant organic materials that would not be removed by a sand or expanded clay. Carbon then serves an additional and very important function in wastewater treatment; this markedly increases the cost-effectiveness of the activated carbon and usually justifies the additional cost of the media. In such a system, biological activity is really a secondary function of the activated carbon so the primary cost distribution relates to the first function, namely the adsorptive removal of organic material. The additional biological growth does in fact help to extend the useful life of the carbon between regenerations and consequently minimize the cost of an activated carbon system. It also provides for some removal of organic fractions that are not strongly adsorbed. Weber indicated no difficulties with respect to application of oxygen to an expanded bed activated carbon system, nor to his knowledge of any physical difficulties that had been experienced in the addition of air to expanded bed sand filters. Indeed, he indicated oxygen transport to the biological surfaces is facilitated and enhanced in an expanded bed system where all of the surfaces, or a larger fraction of the surfaces, of the granular media are available for transport. With respect to the suspended solids control, most activated carbon systems are two stage systems. If suspended solids control is a potential problem, one logical way to use such systems would be to have the first stage adsorber operating in expanded bed mode and the second stage adsorber operating in packed bed mode.

D. Other Observations and Comments

Most observations and comments are covered in the detailed accounting of floor discussions given above. Of particular additional note is the observation that the considerable interest displayed in this session appears also to carry over to the forthcoming IAWPR Conference on Advanced Treatment and Reclamation of Wastewater scheduled for South Africa in June 1977. Many in attendance at this session indicated their interest in presenting results of related studies at the Johannesburg Conference. The integration of biological treatment systems with physicochemical treatment systems for advanced treatment and water reclamation is clearly of international interest.

IV CRITIQUE OF SESSION

As indicated in D above, the papers of this session were generally well received and aroused a substantial amount of interest and discussion. The papers were not particularly original in concept or detail to those who have been conducting active research in these areas but, since this latter group is relatively small in size, the material was relatively original to the majority of the participating audience. The quality of the papers was generally acceptable although one or two, most notably paper No. 46 by Faup *et al.*, could have been much improved had the authors been aware of and used the substantial body of literature and information already available relative to the subject matter of the presentation.

The format of the session was excellent with only a brief summary of the paper presented by the author and a considerable amount of time allowed for discussion. In this regard, however, it is important that the preprints be distributed sufficiently in advance of the meeting to allow participants time to read and review the papers of most interest to them. With such a format, the role of the formal discusser becomes somewhat more critical.

The disadvantage of the format, and this was changed in some sessions, was that the speaker did not respond to the discussion until all discussions (formal and floor) had been presented. This had an adverse effect on continuity and resulted in several points being missed in the response and/or lost out of context.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

In that physicochemical processes are becoming more and more prevalent in the U.S. wastewater treatment technology and applications, this session was one of the more pertinent sessions - relative to U.S. pollution control problems - of the Conference. Of particular interest is the possible integration of physicochemical process technology with conventional (and not-so-conventional) biological process technology. Advances in this area will have significant implications for simultaneously achieving higher degrees of treatment while maintaining reasonable capital and operating costs for water pollution control, both in industrial and municipal wastewater treatment. It would seem appropriate to place a much stronger emphasis on developing and optimizing integrated waste treatment systems.

I. SESSION

A. Theme of Session: Stabilization Ponds

B. Papers Presented:

49. Recirculation Ponds - Pilot Plant and Field Studies.
G. Shelef, M. Ronen, M. Kremer (Israel)

52. Seepage from Oxidation Ponds.
E. Idelovitch (Israel)

55. An Integrated High Rate Pond-Algae Harvesting System.
J. C. Dodd, J. L. Anderson (Australia)

II. REVIEWER

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B. Position and Affiliation: Assistant Professor California
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III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 49

The major emphasis stated in this paper dealing with the operation of multiple stage oxidation ponds is on the effects of recirculating partially treated effluent back to be mixed with the raw sewage influent. Data from a full scale plant are presented showing the effect of the recycle ratio, recycle rate/feed rate (R/F), on BOD_5 removal in the first three pond stages at two organic loading levels. Pilot plant results showing the effects of R/F on the sulfide concentration in the surface water of the first stage are given in addition to the effects on BOD_5 removal in this small two-stage prototype system. Much additional data on algae counts and identification, COD, suspended solids, dissolved oxygen, pH, and operating temperatures in various stages were also presented without specific correlation to recycle ratios. Finally, the effluent from this plant (Dan River Region in Israel) is to be used for long-term ground water recharge. During operation since 1969, the biological treatment effluent has not met the quality requirements for this use. A final sludge-blanket lime clarifier is to be used to finish the treatment. The effluent levels of BOD, COD, TSS, nitrogen compounds, phosphate, and detergents from a pilot plant clarifier operating with 3rd stage pond effluent are tabulated together with the final quality following ponding of this effluent for NH_3 removal.

The most important conclusions reached were that recirculation immediately solved the severe odor problem experienced during the initial operation in 1969. The first pond, receiving raw sewage, was strongly anaerobic and considerable sulfide concentrations were present at the surface. Recirculation of water with considerable DO from a later stage pond satisfied the immediate oxygen demand and allowed normal reoxygenation at the surface to maintain a sulfide-free top layer. A second benefit of recirculation was found to be an increase in the aerial loading capacity. The optimum R/F for maximum loading (about 400 kg/Ha-day) in this system was found to be about 2/1, the recycle being 3rd stage effluent.

A.2 Paper No. 52

The subject of this presentation was the measurement of seepage rates from the Dan Region treatment ponds discussed in the first paper. Seepage was computed from a simple water balance in which the seepage was the unaccountable portion after all other sources and sinks had been quantified and balanced. Two sets of ponds are compared - one without linings and one set with compacted clay linings. The major conclusion to be drawn from the data is that the unlined ponds (in this case constructed on sand dunes) after a few years of operation approached the seepage rates of clay lined ponds after a similar period of use. It was suggested that the most important issue in the decision to line treatment ponds with clay is the possibility of seriously polluting ground water during the early months of operation of unlined ponds. The data showed that after four years the seepage rates were quite stable in both systems, but still not near zero. The latest seepage rates were reported to be 7-8 mm/day.

A.3 Paper No. 55

The two key elements in the algae harvesting system described are: the control of the type of dominant organisms produced in an oxidation pond with wastewater feed and the development of economical and efficient filtration techniques. The input wastewater for the testing described was the effluent from a primary treatment plant with "average" BOD_5 and COD of 405 and 733 mg/ℓ, respectively. No data from the pilot operation were presented but estimates of removal efficiencies for a full scale system, based on pilot plant operation, were said to be in the range of 90-95 percent for suspended solids and BOD_5. The high rate pond, much resembling the Pasveer system or oxidation ditch, was lime treated to raise the pH from near neutral to the range of 8.3 to 9 pH, which maintained the predominance of the more readily filterable *Scenedesmus* sp. over the smaller *Chlorella*. The separation of algae from effluent was accomplished by vacuum filtration on a paper medium formed directly beforehand on a continuous belt septum using the Fourdrinier process. Most of the data concerned the separation of the algae solids from the paper filter medium after filtration by a two-stage vacuum backwash where the paper is supported in a belt sandwich by an auxiliary belt. The algae pass through the auxiliary belt. Using the two stages of vacuum backwash plus two stages of wash following repulping of the paper filter medium, less than 1.5 percent of the algae remained with the pulp. Most of the discussion is devoted to a description of a proposed full scale 100 megaliters/day (Mℓ/day) plant with flow diagrams and cost estimates. These show an estimated annual cost nearly one-third lower for the harvesting system than for an alternative "conventional" secondary treatment system using methanol as an auxiliary carbon source to attain denitrification to the levels projected for the harvesting system. This estimate depends on the recovery of nearly one-third the cost of plant operation by sales of the algal product at \$140/tonne (\$200 market value). The average crude protein content of the algae concentrate was 53 percent. Heat treatment was proposed to destroy pathogens and improve the digestibility of the product algae.

B. Prepared Discussions

B.1 Mr. C. D. Parker from Australia suggested a possible connection between the responses of both the pond system and trickling filters to recirculation of effluent. In both cases the loading on a unit could be nearly doubled by the use of recirculation. Experience with trickling filters has indicated that concentrations above a maximum of about 100 mg/ℓ of BOD_5 applied to the filter inhibits algal growth. Further work with higher strength wastes is needed to develop design principles for recycling pond systems that might be appropriate for industrial wastes with much higher strengths, say 5 to 10 times those reported in these Dan Region tests. If the requirement for influent BOD_5 concentration of 100 mg/ℓ or less really applied to ponds, 1500 mg/ℓ wastes would require a 15:1 recycle ratio. The question of pumping energy in this case will be an important trade-off against increased pond area to keep the loading down. The reasons for the sulfide increase with "loading" in the pilot plant and the type filter used in determining dissolved BOD_5 were questioned. Dr. Shelef responded that the reason for increase in sulfide with R/F, when R/F = 2, is: sludge raised by turbulence. The suspended solids were removed with Millipore membrane filters to determine dissolved BOD_5 on the filtrate.

On the matter of design for higher strength wastes, the author agreed that something better than recirculation alone would be needed because of the high pumping energy requirements. The upper limit for economical pumping was stated to be about R/F = 3, while ratios above 6 result in operation of the whole system as a completely stirred reactor.

B.2 The discusser asked about water table conditions, depth to the clay layer and sand size. The answers were that little change in level was observed, with both the water table and clay lining at about 7-8 meters depth. The sand was about 1 mm size. It was suggested that suspensions of clay and/or silt might be employed with coagulants to seal the pond bottoms before operation, to reduce the initial loss of polluted water.

B.3 Dr. Shelef discussed heavy metals in the product saying that the mere presence of toxic metals, and *Salmonella*, does not define a problem. Lead in foods has been found in some cases to be directly eliminated and not be assimilated. Only extensive feeding and inspection of the flesh can define the scope of intoxication by contaminated feed. It was also pointed out that under good conditions one hectare of algae pond can produce 110 tonnes of dry algae per year; this is about 10 times the productivity of soy beans, one of the highest yield high protein alternatives. Prof. Oswald stated in his written discussion that the system may be too complex for developing countries where the trend should be towards simplicity. Dr. Shelef described work in Israel on an algae recovery with a simpler system using alum floc for seperation by flotation followed by acid washing, pH 3.5, to remove the aluminum and readily soluble heavy metals. The product was successfully fed to chickens.

C. Floor Discussions

C.1 The lively floor discussion centered on the operation of the first stage pond and recycling. Step feeding was proposed as a superior alternative to recycling. It was also proposed for augmentation where very high strength wastes are treated. Auxiliary floating aerators were also suggested for use in augmenting the reaction rates in the first stage ponds. The point was made that some background is already available for designing the first stage pond. The first stage pond may be considered as two cells, one anaerobic and one facultative - photosynthetic. The depth of the first stage should be determined by the maximum anaerobic sludge volume required to digest the settleable solids. Month-by-month calculations based on temperature (reaction rate) and mass balance have been used by Dr. Oswald at the University of California-Berkeley to size the anaerobic cell. The consensus of the group appeared to be that a great deal more work is needed before the multiple stage pond treatment is well understood. For example, is stratification a problem? It was stated from the floor that stratification could result in serious short circuiting (actual detention times 0.1 of those calculated). Dr. Shelef pointed to the experience in Israel where the small pilot plant ponds stratified daily but wind prevented stratification of the full scale treatment ponds. A possibly significant advantage of using an anaerobic first stage is the destruction of pathogens. Schistosomes were said to be destroyed in anaerobic digestion if their detention time is sufficient.

C.2 An experience with a pond in sandy soil was described in which the extremely high infiltration rate did not change over an eight-month period with an influent with much higher solids concentration than the Dan Region water. It was suggested that the high pH may have led to precipitation of solids to block the interstices.

D. Other Observations and Comments

The general response of a number of Australians to the two papers on pond lining and algae recovery was rather critical. The consensus was that pond lining is still very much an unresolved problem. For example, both butyl and hypalon have been used. Fatty acids attack hypalon. One lagoon lining developed hundreds of methane bubbles in one year which were lanced like boils to relieve the pressure. The algae recovery project has been extensively examined by the Bureau of Studies of the Department of Housing and Community Development in a yet unissued report titled "Planning for the Use of Sewage." A. G. Strom, Director Civil Engineer, stated they have found this system too expensive and are concerned about pathogens in the product.

IV. CRITIQUE OF SESSION

The presentation of operating and descriptive data for the Dan Region pond system brought interested response with much floor discussion of the first two papers. The value of the exposition of this technology for low energy treatment is probably best illustrated by the difficulties encountered in operation of this plant in 1969-70 shortly after start-up without recirculation although two similar systems were already operating with recirculation in other countries 10 years earlier. The amount of data shown represents only a tantalizing beginning. Variables such as pH, temperature, dominant microbe population, suspended solids, and DO were reported but not correlated to recycle ratio or BOD removal. Pond configuration details such as inlet and shape for flow control and depth cannot be optimized without much more study. Enough has already been done to point the way to successful, if not optimum, designs for pond treatment of raw sewage. The report on seepage will not be much help in designing pond seals.

The separation of algae using an *in situ* paper-forming machine is an innovative approach to one phase of what might be called sewage farming. The importance of using selective growth methods to produce algae with special properties such as large size and digestibility complicate the process. Very little data were presented to establish the parameters of operation of the system. The elaborate economic analysis is perhaps premature except to suggest that further study is warranted. Very little floor discussion was heard, but individuals showed interest after the session. Other methods of separation using coagulants such as alum are thought to be simpler, but run the risk of toxicity (aluminum is toxic to chickens). The question of botulism was not raised in any of these talks, though it has been observed in some anaerobic pond systems.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Oxidation pond technology is already becoming established with the building of over 500 Pasveer systems in the U.S., principally in Texas and Maine (Halvorson, 1976). The development of real sewage farming has been difficult to realize because land costs and the fear of pathogen transmission are major concerns. It was pointed out in this session, however, that pond protein productivity is far higher than that of dry land farming. Algae used for animal feed may be heat sterilized. These systems seem unsuited to present high density metropolitan areas, but in suburban or in more rural settings the land may be available and markets for high protein feed products may be close enough to make sewage farming the treatment of choice. The work reported represents important feasibility studies. What is missing is sufficient design information either to optimize the pond-harvesting process or to compare these processes to other alternatives. Other alternatives include using fish as harvesters of the algae (Carpenter, 1976; Dinges, 1976); Dr. Shelef stated that such schemes are receiving attention in Israel. Algae are now worth $100 to $200 per tonne as feed. If the fish conversion is 10 percent efficient (2nd trophic level), a tonne of algae produces 100 kg of fish - possibly worth $1.00/kg - but much easier to harvest. The textbook viewpoint of sewage as a nuisance in the 60's and the admonition to use energy to subsidize processes to reduce capital costs is rapidly changing to the idea that the nutrients are a resource to be recovered and energy conservation is imperative, at least for the next decade or two. Present information suggests that economical pond systems with biological treatment have potential to produce superior effluents at low cost in energy, or even a net gain, counting solar input to produce food products. Research is needed to learn how to control the growth of destructive organisms such as some of the cyanophytes (Keating, 1976) while promoting the growth of desirable species. It is not now clear if or when vascular plants (bullrushes, etc.) or animals such as brine shrimp or fish should be used. There are pro (McKinney, 1967) and con arguments about the role of micropredators (rotifers, voricella, etc.) as well as the symbiotic relations between the algae and bacteria in using and producing oxygen (Bartsch, 1957). Answers to these questions are needed before system optimization to meet water quality requirements for reuse becomes a science.

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I. SESSION

A. Theme of Session: Sulfide Attack on Sewers

B. Papers Presented:

38. Simulation of Design-Storms with Probable Distributions in Time and Space for Storm Drainage Systems.
F. Sieker (Germany)

41. The Significance of Stormwater Runoff in an Urbanizing Watershed.
C. W. Randall, J. A. Garland, T. J. Grizzard, R. C. Hoehn (USA)

44. Prevention and Protection of Sewerage Systems Against Sulphide Attack with Reference to Experience in Singapore.
A. Nadarajah, J. Richardson (Singapore)

47. The Forecasting of Sulphide Build-up Rates in Sewers.
R. D. Pomeroy, J. D. Parkhurst (USA)

II. REVIEWER

A. Name: Ivan L. Bogert

B. Position and Affiliation: Partner, Clinton Bogert Associates
Fort Lee, New Jersey

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 38

This paper provides a method of developing the design storm for storm drainage systems from rainfall data. The design storm intensity may vary with time and space.

Most drainage systems are still designed by the rational method for a design storm of a specified duration and return frequency. The design storm has a uniform distribution of rainfall in time and space. It implies that the frequency of rainfall is equal to the frequency of runoff. This is incorrect in reality since rain storms of the same duration and the same amount but with different storm patterns will result in different peak and distribution runoff.

The proposed method analyzes point rainfall data at several rain gauges using a multi-variate statistical technique of variance analysis. While the total amounts of rainfall at a given station point are independent from rainfall event to event, the method considers time-dependence and space-dependence of rainfall within a given rainfall event. Irregularity of rainfall is expressed in terms of components which are evaluated. These are developed with respect to time in three factors - mean distribution in time, exceedance probability factor, and random factor (which cannot presently be defined). The distribution in space is defined by five factors - mean distribution in space, exceedance probability factor, drift factor due to winds (occurs in strips), anti-drift component (which is not defined physically), and a random factor (which also cannot be defined physically).

The design storm is corrected by the ratio of the average rainfall depth obtained from a frequency analysis of the total rainfall amounts and the amount of simulated design storm.

The speaker indicated that some of the equations (bottom of page 515 original paper) have been corrected and simplified since the paper was prepared two years ago.

A.2 Paper No. 41

Field samplings were made during and after rainstorms with depth ranging from 0.3 to 0.8 in. at selected locations of varying land use types. The sample analysis shows that 1) organic concentration in runoff approrches that of secondary sewage treatment effluent, 2) urban runoff contains far greater loadings of suspended solids, organic matter and nutrients entering the stream than a secondary treatment plant effluent; and 3) more diversifiud urban area produces considerably more pollutant loading per unit area of all pollution parameters than a single family residential area.

The data indicate that non-point sources must be controlled or additional organic removal at treatment plants cannot be justified. The amount of nitrogen and phosphorus removal which can be justified at treatment plants is now being studied.

A.3 Paper No. 44

This paper deals with hydrogen sulfide problems in general and with Singapore's case history in particular. Temperature is particularly important to the incidence of sewer corrosion which is far greater in tropical and subtropical areas than in temperate areas.

The paper describes the precautionary measures against hydrogen sulfide attacks as 1) "prevention" by designing a sewerage system and conditioning its environment to forestall the onset of septicity, and 2) as "protection" by constructing the sewer with corrosion-resistant materials.

An example of the corrosion problem in the Singapore Sewerage System is a 13 mm (1/2 in.) thick lining, of high aluminum cement mortar, in an 1800 mm (71 in.) diameter concrete pipe which was completely corroded after 9 years in use.

The experience on which the paper is based is related to Singapore's conditions, i.e., material availability, expertise, and last, but not least, economy.

A.4 Paper No. 47

This paper discusses three formulas for estimating sulfide build-up in filled pipes and points out that predictions in partially filled sewers are much more complex. Based on studies at Los Angeles County Sanitation District, it was believed that a complete equation to estimate sulfide concentration could be established, based on the factors involved. However, obtaining all the data is not practicable because much data cannot even be obtained. Therefore, a simpler equation is presented only related to those conditions where BOD, DO and sulfur concentrations are most favorable to the generation of H_2S. These restrictions inherently result in the equation giving conservative values. Consequently, the equation becomes useful in engineering where the worst sulfide conditions need to be known in sewer system design.

The model represents the rate of change of sulfide concentration as the sum of the input from the slime layer determined from BOD and temperature, minus the losses due to oxidation rate and H_2S volatilization determined from the sewer energy line slope, stream velocity, mean hydraulic depth and existing sulfide concentration.

B. Prepared Discussions

B.1 Paper No. 38 - Sueishi, T. (Japan)

a. This method appears to be usable in all situations and would be most valuable when used in connection with computer discharge methods.

b. It was noted also that overflow possibility is greatest when the rain clouds are moving in the same direction and speed as flow in the sewers.

B.2 Paper No. 41 - Parker (Australia)

a. Are there any overflows or small industries into this drainage system?

Reply - The system is all separate sewers with little industry but some shopping centers.

b. Would settling of storm runoff significantly affect nitrogen and phosphorus?

Reply - Yes; it would also affect the TOC.

c. Are there any agricultural runoffs into streams of this area?

Reply - All runoff is from urban areas. Upstream hydrograph, which has some rural areas, did not change during this particular storm.

d. The validity of using a single storm episode to calculate annual figures was questioned.

Reply - Since the average storm during a year is about 0.45 in., it appeared that the use of the particular storm, which averaged 0.51 in., was reasonable as a starting point for studies.

B.3 Paper No. 44 - Hall (South Africa)

a. They have found liners not generally adequate but corrosion-resistant pipes more suitable. An alternative would be to use dolomitic aggregate with a sacrificial layer. For tunnels use dolomitic aggregate concrete.

b. Spun pipe with silicious aggregate did not hold up.

c. They also use brick liners where turbulence occurs.

d. Inquired what has been done to protect joint material.

Reply - Top wax resin coats over cement joints were placed after construction.

B.4 Paper No. 47 - Eden (U.K.)

a. There are problems in the United Kingdom but most in rising (force) mains. They are using oxygen to combat this, using 7 kg per week in the smaller ones and 9 tons per week in the larger ones. BOD reductions were quite significant.

b. Has effect of nitrate been considered?

Reply - Nitrates may prevent H_2S formation. In sewers, no effects were found initially but appeared in two or three days.

c. Basis of assumptions on sulfide buildup and oxygen consumption rates appear questionable and based more on empirical comparison with results.

Reply - Many assumptions were determined theoretically by Dobbins and checked by them empirically.

d. Feels figures in Figure 2 (original paper) are too high and that, in practice, no buildup occurs in many cases where buildup is predicted by formulas.

Reply - Buildup occurred for them.

C. Floor Discussions

C.1 Paper No. 38

Cosgrove (Canada). Postulate used in sewer system design to date (and retained by the author) that rainfall frequency equals discharge frequency does not hold. An example was given where an upstream moving storm resulted in 4-hour discharge time while a downstream moving storm of the same character resulted in 3-hour discharge time. Therefore, each would have different hydrograph shapes and peaks.

Reply - This matter is still open and not intended to be covered by the paper. Studies had not gotten to a point of combining time with space distribution. Also, complete variations for a 6-hour storm would cost $10,000 in computer time. In addition, there are measurement problems since recorders frequently malfunction and can be a quarter or a half hour out, which completely changes the nature of the analysis. A system to provide simultaneous plotting of records on one chart may help in this respect.

C.2 Paper No. 41

Sueishi (Japan). Their data on pounds per day today are similar to those produced in this report.

Comment from participant from Norway. Method of calculation of averages appears to be on the high side.

Perry (U.K.). They find a large difference (particularly in oil content) based upon the length of time prior to the storm at which the last prior storm occurred.

Barnes (Australia). Have lead levels been checked?

Reply - Lead and iron are very high; also, there are other metals in significant amounts.

Van Rooyen (South Africa). To what extent are toxic blue-green algae present?

Reply - They are present in late fall. There are taste and odor problems which they use copper sulfate to correct.

Are toxins removed by water plant?

Reply - No, better methods of water treatment are required, however, rather than more advanced sewage treatment.

Participant from South Africa. Wouldn't more use of automatic samples have been worth the cost?

Reply - Have now gone to automatic equipment for further studies.

C.3 Paper No. 44

Cosgrove (Canada). Proper maintenance is essential no matter what the construction. Can anyone report on lined pipe problems with newly designed, properly maintained sewers?

Reply - In the East, toilets are not flushed as frequently as they are in Western countries. Accordingly, sewage becomes septic earlier and there are greater problems in those sewers even when properly maintained.

Browne (Australia). Is the reference to asbestos-cement pipe that does not hold up, high pressure autoclave steam cured pipe? They have found this gives superior resistance to pH of 4.

Reply - Yes, it is high pressure pipe. Also, would be more resistant to pH since there is less concrete, 50 percent in the high pressure pipe compared to 83 percent in regular A.C. pipe.

Goleb (Australia). There is some evidence that old sewers not previously exposed to acid conditions were more resistant when exposed to acid conditions than new sewers.

Parker (Australia) In many systems, as flow builds up, problem diminishes.

Reply - Yes, but has been high in their case.

There should be more investigation into the chemistry of cement. They also found older sewer sections more resistant than the new ones.

Shaw (Australia). Feels that approach of this paper is accepting the hydrogen sulfide buildup rather than attacking it. Suggests use of pure oxygen and counter current treatment which can build up 20 ppm oxygen which would last for perhaps 10 miles. Studies of the rate of fall of BOD after oxygenation indicate it would also result in pretreatment benefits. In fact, they estimate that secondary treatment can be carried out in a sewer system at a cost of $0.05 per thousand Imperial gallons.

Reply - As stated before, in many cases sewage is already septic before it gets into the sewer and, accordingly, hdyrogen sulfide is present at the time it enters the sewer.

C.4 Paper No. 47

Barnard (South Africa). Should distinguish between turbulence before septicity which is good, and after sewage it becomes septic, which is bad.

Reply - Yes.

Lovell (Australia). It would be desirable to gather information for a curve on critical grades for various size pipes.

Parker (Australia). Sulfate content of water supply should also be considered.

Roberts (U.K.). Feels equations are generally tied to average conditions and do not reflect extreme conditions.

Reply - Need to consider these special conditions as a separate matter.

Recommends construction of house connections at the same time as laterals to eliminate initial low flow conditions.

Suggest a special conference on the subject of sulfide in sewers.

Participant from Germany. Agrees on the need for special conference. There has been an increase in Germany over the last few years in sulfide problems.

D. Other Observations and Comments.

None

IV. CRITIQUE OF SESSION.

In general, the four reports were well received. The papers were all high quality and were of matters of interest. Comments on specific items with regard to certain papers are listed in Section V.

Although the method (Paper No. 38) appears to provide a logical derivation of design storm using rainfall data, there are other practical methods being used to derive a design storm for storm sewer design. These practical methods are developed as the result of increasing use of the hydrograph method instead of the rational method for storm drain design. The hydrograph is arranged so that it conforms at all points to the applicable intensity-duration curve which is readily available from the U.S. National Weather Service publications. The time of peak rainfall within the design storm is determined from analysis of observed rainfall which is generally classified as having an advanced, intermediate, or delayed peak. Storms of intermediate and delayed patterns produce greater runoff rate and volume than storms of advanced pattern. These methods are simple to apply and are widely used in the U.S.

The proposed method requires the digitization of rainfall data in short intervals (as short as 5 minutes) for many years of observation. The U.S. National Weather Service can readily provide hourly data for most weather stations. To obtain shorter interval data, however, special service is required.

Although limited samples were collected, the study findings (Paper No. 41) are consistent with storm water runoff studies conducted in other U.S. urban and semiurban areas, such as Philadelphia; New

Brunswick, NJ; and Durham, NC; etc. These findings point out the needs for comprehensive water quality planning of both point and non-point sources. These needs have now been generally recognized. The ongoing 208 area wide wastewater management study in many parts of the country aims at achieving such a goal.

There is no critique of Papers No. 44 and 47 other than as given in Section V.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Paper No. 38 covers a matter of considerable importance to U.S. water pollution control problems. The proposed method, however, appears to be proceeding in a direction of considerable complexity and, to evaluate the method for practical application, would require a comparison study using the proposed method and the methods presently used. In such comparative studies, one should also keep in mind that there are many other factors affecting the storm drain design, including the concept of using storm drains for pollution control.

Paper No. 41 is of considerable importance to American water pollution research and construction activities due to the serious question raised regarding the cost effectiveness of expending considerable sums for more advanced waste treatment at sewage treatment plants without considering in the balance the effect upon the receiving waters of non-point sources, as well as combined storm drain discharges. Further research and studies should certainly be carried out into the effect of storm water runoff, not only from point sources but non-point sources, both from urban watershed and other types of watersheds, to determine more accurately the effects of same upon receiving waters. Studies should also be carried out of a procedure for economic and environmental evaluation of such sources of pollution, together with the pollution from sewage treatment plants.

Paper No. 44 presents a more extreme case than is usual in most areas of the U.S. and the differing economic conditions would also affect the comparative cost-effectiveness of providing protection against sulfide attack. Certainly further research could be carried out under conditions applicable to areas in this country.

In addition, floor comments regarding the higher resistance of older installations certainly warrants further research in this area.

Further, of the linings considered for the Singapore sewerage pipes, the resin impregnated terylene lining is of most interest. The lining is formed by the introduction of a terylene fiber blanket into the sewer, impregnating it with resin and forcing the blanket against the sewer wall by pneumatic or hydrostatic pressure until the resin sets. The resulting lining, which can be from 5 mm (3/16 in.) to 15 mm (1/2 in.) thick, is rigid and self-supporting. Further investigation appears warranted.

Paper No. 47 is important as the basic determinant of whether a sulfide problem does exist or will exist. It would appear, however, that further studies should be carried out on this matter to be able to evaluate not only the extreme conditions presented, but also average conditions which would be important in evaluating protective measures versus use of sacrificial layers or of chemicals to counteract the sulfide.

I. SESSION

A. Theme of Session: Automation and Aerobic and Anaerobic Digestion

B. Papers Presented:

50. Current Status of Research in Automation of Wastewater Treatment in the United States. J. F. Roesler, D. F. Bishop, I. J. Kugelman (USA)

53. A Comparison of Pure Oxygen and Diffused Air Digestion of Waste Activated Sludge. D. B. Cohen (Canada)

56. The Dynamic Behavior of an Anaerobic Digester. A. D. Carr, R. C. O'Donnel (South Africa)

II. REVIEWER

A. Name: W. Wesley Eckenfelder, Jr.

B. Position and Affiliation:
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III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 50

The first paper reviewed the current status of research in automation in the United States. From the paper it is apparent that the application of automation to municipal wastewater plants has seriously lagged in design and construction of large treatment plants. While several reasons were cited in the paper the paramount ones were: a) lack of suitable models to base the control mechanisms on, b) lack of reliable sensors, and c) lack of trained personnel to operate and maintain such equipment. The USEPA has initiated a program to overcome these deficiencies through a newly organized Advisory Committee on Instrumentation and Automation for Wastewater Management. It was further brought out in the paper that a significant cost effective impact or improved effluent quality control needs to be defined to justify widespread use of such controls.

A.2 Paper No. 53

The second paper was "A Comparison of Pure Oxygen and Diffused Air Digestion of Waste Activated Sludge," by David B. Cohen of Canada. The paper developed several pertinent points, namely that sludge dewaterability by vacuum filtration was improved after air digestion of dilute sludge, but adversely affected by oxygen digestion of thickened sludge, that the maximum effective loading for diffused air digestion was a loading rate of 0.08 lbs VSS/ft^3/day. Oxygen digestion was successfully accomplished at loadings up to 0.433 lbs VSS/ft^3/day. An open tank oxygen diffusion system was used in this study. The authors conclusions would indicate advantages for oxygen digestion due to the ability to digest thickened sludge resulting in reduced space requirements and higher digestion temperatures from exothermic heat. This would be offset in some cases by increases in chemical conditioning dosages to obtain equivalent vacuum filtration performance as compared to air digestion.

A.3 Paper No. 56

The third paper discussed the application of a mathematical model to the prediction of changes in anaerobic performance. The paper itself used a theoretical model developed by the senior author with a synthetic substrate under controlled operating conditions. Agreement between prediction and response in most cases was good.

B. Prepared Discussions

B.1 W. Von der Emde presented the prepared discussion on Paper No. 50. In discussing the municipal wastewater treatment plant at Blumental, Vienna, he showed that a variety of automation and control had been in effective use for a number of years. This includes storm water control through the use of the sewer level sensors (Roesler *et al.* indicated that this type of control was presently in use at Seattle, Washington, although no results were reported). Other controls at Blumental include F/M control for return activated sludge and sludge digestion control by measurement of the methane content of the gas. Von der Emde's discussion would indicate that while automation and sensors are in an equal or advanced state of development in the U.S, the application to real world situations is more advanced in Europe.

B.2 W. Eckenfelder discussed Paper No 53 and brought out several points which require consideration from an engineering and economic standpoint. The limitation considered for the use of air relates to the oxygen transfer and mixing capacity of an air diffusion system. Other equipment such as a submerged turbine which induces more shear and turbulence and a higher oxygen transfer rate would allow higher solids loadings to the digester.

Temperature effects were not fully defined. Studies by Union Carbide using oxygen have demonstrated the feasibility of thermophilic aerobic digestion due to the high exothermic heat input and relatively low heat loss. By contrast, all other things being equal, an air system would usually operate with lower solids loadings, higher heat losses and consequent lower operating temperatures. A thorough engineering analysis of temperature relationships in alternative systems is needed to resolve the economics of air vs. oxygen for specific situations.

The character of the sludge fed to the digester, i.e., sludge age, entering the system needs to be considered. A high sludge age would have significantly less degradable VSS present and overall VSS reduction for any time-temperature relationship would be less. Failure to consider this factor could lead to misleading conclusions. The paper provides useful information on the application of aerobic digestion but the limitations relative to the equipment used and the mode of operation must be considered in any field application.

B.3 The formal discusser, H. Schoenfelder of the Federal Republic of Germany, discussed municipal sludge digestion practices in Germany which did not relate to the paper.

C. Floor Discussions

C.1 The floor discussion primarily related to the need for operator training in the use and maintenance of instrumentation and controls. In addition, more technical training is essential on the mechanisms of wastewater treatment in order to develop an understanding of control response and adjustment. It becomes evident to the writer that a number of actions need to be initiated or continued (some of these are already in a formative or functioning stage):

1. Practical models defining the various stages of the wastewater treatment plant need to be developed and field tested. Over the years many models have been professed particularly for biological wastewater treatment processes such as the activated sludge process. Few, if any, of these have been adopted by either the design engineer or the plant operator. The primary reason is that the models are too complex, require knowledge of parameters and coefficients that are not obtainable in the real world, and were developed on known substrates under controlled conditions which do not reflect field conditions.

2. The operator's professional status and resulting salary level needs to be established particularly in the municipal field. While certification has helped this situation over the years, a large gap still remains in most cases between the professional competence needed to perform the job and the salary levels offered.

3. Training courses or programs to provide the technical knowledge needed to understand and interpret the complexities of the wastewater treatment processes are necessary. While many operator training programs are available, few of these provide the depth of technical understanding needed to effectively operate under optimum conditions the increasingly complex and sophisticated wastewater treatment plants of today and the future.

C.2 An interesting point was made in the floor discussion of Paper No. 53. The author noted a significant reduction in invertebrate biomass in the oxygen digester, possibly due to crowding in the oxygen digester and the higher operating temperatures. Rincke confirmed from studies in Germany that thermophilic aerobic digestion reduced or eliminated protozoa and rotifers but that thermophilic digestion followed by mesophilic digestion reintroduced invertebrates to the system with resulting improved dewatering characteristics. Based on the paper and the discussion, this writer arrives at the conclusion that additional work is needed to define both the engineering and process characteristics of aerobic digestion. While much of this information is presently available, a logical correlation of such information is needed and a defined program for additional studies developed.

C.3 The floor discussion (Paper No. 56), while not relating directly to the paper, opened a major philosophical issue. Both Alan Molof of New York University and D. Wexler of Canada raised the issue of the practicality of such a model to engineering application and practice. The author conceded that many of the parameters in the model could not be measured or defined in practical application. Dr. E. Pearson of the University of California defended the model approach as leading to a greater understanding of the mechanisms of the anaerobic process. As a conclusion to this discussion the writer feels that a major portion of the research generated in universities and research institutes is esoteric and, while providing advanced degrees to students, is not useful to the practitioner in the field. It would seem that the question should be raised in a paper such as this - how can this be applied to practice or, if not directly, what additional research would be needed to make the results useful. These observations apply, of course, to much of the research presently being conducted in this field.

IV. CRITIQUE OF SESSION

This session was a "mixed bag." The first paper on automation, while not a research paper as such, defined a need and research objectives to attain. As such it is very useful to all researchers in this area of activity. The second paper on aerobic digestion provided interesting and useful information but must be interpreted with caution. A more comprehensive analysis of the problem is needed before meaningful engineering conclusions can be drawn. The third paper on anaerobic digestion provided a theoretical analysis of anaerobic dynamics. While the response to controlled and known substrate conditions was good, application to the real world is questionable.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Aerobic digestion is widely used in the United States and design practice and economics is very important to present and continuing water pollution control programs. The paper suggests needed areas of research. The paper on anaerobic digestion suggests needed research in the conversion of theoretical models to engineering practice.

I. SESSION

A. Theme of Session: Industrial Wastewater Management

B. Papers Presented:

39. Fellmongery Waste Treatment - Comparison of Cost and Degree of Treatment.
H. Melcer, P. N. McFarlane (New Zealand)

42. Treatment Alternatives for Wastewaters from the Tapioca Starch Industry.
M. B. Pescod, N. C. Thanh (Thailand)

45. Process Design Investigations for Alaska Pulp Mill Wastewater Treatment Facilities.
H. Edde, R. French, D. Mason, T. Hosoi (USA)

48. Measurement and Treatment of Oil and Grease in Petroleum and Petrochemical Industrial Wastewaters.
L. F. Tischler, R. L. Elton, III,
D. L. Ford (USA)

II. REVIEWER

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III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 39

This paper gives the cost-effectiveness of treating wastewater in New Zealand. Three methods were discussed: catalytic oxidation, bio-filtration with a trickling filter, and an aerobic lagoon. The characteristics of these wastewaters after treatment by these three methods are shown in Table 1.

Table 1

Parameter*	Raw Effluent	Catalytic Oxidation Effluent	Bio-Filter Effluent	Lagoon Effluent
BOD	2,000	--	1,200	133
COD	3,600	2,100	2,000	850
Total Solids	11,000	--	--	4,600
Suspended Solids	1,000	310	--	600
Total Nitrogen	400	--	1.0	1.0-10.0
Total Sulfide	200	0	--	7.9
pH	11.5	11.5-12.0	10.0	--

*Units in mg/ℓ, except pH

The following is a summary of capital and operating costs:

Table 2

Method of Treatment	Capital Cost	Annual Operating Cost
Catalytic Oxidation	$135,200	$44,600
Bio-filtration	85,000	2,900
Anaerobic Lagoon	62,500	700

The plant described mixes concentrated dehairing and liming wastewaters with the very concentrated soaking and deliming water. As a result of this practice, the sulfide concentration in the wastewater is sufficiently diluted (200 mg/ℓ) so that the stream may be treated biologically with no sulfide toxicity problems. In all the systems it was assumed that adequate screening and sedimentation preceded the basic treatment unit. Equalization was provided for catalytic oxidation and bio-filtration; however, the anaerobic lagoon was so large that equalization was not required. Cost information was taken from reference tables.

The catalytic oxidation scheme employed $KMnO_4$. In the U.S. manganous sulfate is often used because it is more economical. However, in New Zealand the price of these two chemicals is similar and, therefore, the more efficient $KMnO_4$ is used. The manganese/sulfide ratio was selected at 1:10 and an aeration time of 15 minutes was used, based on literature values.

The bio-filter was assumed to be loaded at 5 to 6 m^3/day and a recycle ratio of 8:1 was used. The pH dropped through the bio-filter to 9.0, while the catalytic oxidation pH remained high, in the range of 11.5 to 12.0. The organic concentration in the effluent streams from catalytic oxidation and bio-filtration was very high and, consequently, additional treatment would be required in order to meet an acceptable effluent for direct discharge to a receiving water.

The anaerobic lagoon was designed using a depth of 2 m and 70 day detention time. No equalization was required. Approximately 93 percent BOD removal, 76 percent COD removal, and 97 percent sulfide removal was observed in a full scale plant. The sulfide removal results were almost as good as the catalytic oxidation effluent. However, the organic removal in the anaerobic lagoon was much superior to the other two systems. The sulfide reduction occurred by purple sulfur bacteria, *Chromatiaceae*. The red color in the effluent was produced but no odor problems were observed during three years of operation.

The conclusions of this study were that the anaerobic lagoon is the only alternative for adequate treatment of sulfides and organics. However, sufficient land is needed and the climate must be suitable to provide sunlight since the *Chromatiaceae* are photosynthetic. If land availability is a problem, the bio-filtration is best. Continuous catalytic oxidation is not considered economically feasible. It is only satisfactory for low volume, high concentration wastewaters which is not the case in New Zealand. Catalytic oxidation systems offer the best operational control, however.

A.2 Paper No. 42

This paper presents a summary of the tapioca starch production in Thailand. Two types of wastewaters are generated, depending on the quality of starch which is produced. The authors recommended that the production waste be separated from the wash water used to clean the tapioca plant roots before being crushed to generate the starch, and that anaerobic treatment be used for first-stage treatment in most cases. Next, the following stages may consist of a series of anaerobic ponds followed by an aerobic aerated lagoon or bio-filter. If land is available, it is possible to follow the anaerobic facultative ponds in series. Two stages of facultative ponds are recommended. If land is limited, the anaerobic ponds followed by the aerated lagoon or bio-filter are recommended. If only an aerated lagoon or bio-filter is used, it should be preceded with primary sedimentation.

The authors also briefly examined single-cell protein production using *Torula* yeast. COD reduction of 73 percent occurred and the yeast mass contained approximately 50 percent protein with 0.5 kg yeast produced/kg COD removed. A nitrogen supplement was required on the order of 1 kg nitrogen/50 kg COD removed. The effluent from the yeast production required additional COD removal; because of this it is not considered feasible.

A.3 Paper No. 45

This paper presented a comparative study of air versus pure oxygen activated sludge treatment of a dissolving acid sulfite pulp mill. It also examined two in-plant options for generating waste streams for treatment in the activated sludge system. One option was to treat the total mill stream, while the second option considered bypassing directly to the chlorination stage of the bleached plant effluent and treating the remaining stream in the activated sludge system.

The authors recommended that the complete mix design was as adequate a treatment as multi-stage or contact stabilization activated sludge systems. Therefore, their studies were oriented toward completely mixed activated sludge. They also concluded that the COD method for determining oxygen requirements was more accurate than the oxygen uptake measurements and, therefore, used the COD method in their comparison. The pure oxygen system required 2 to 3 percent more oxygen than the air system. The pure oxygen sludge thickened 50 percent better than the air (44 vs. 30 lb/sq ft-day on a mass loading basis to the clarifier). The underflow concentration from the secondary clarifier was 4 percent in the pure oxygen system versus 1 percent for the air system. The sludge production was equivalent for both systems. The thickening and dewatering characteristics were much better for the pure oxygen than for air. It was also concluded that the oxygen system was shock resistant and recovered from shutdown much better than air. With air, a 1 week period was required to recover from a 10-day shutdown, where the pure oxygen system responded immediately with satisfactory results. The fuel content of the sludges was about the same at 9,400 BTU/lb.

It was concluded that the pure oxygen system should be operated at higher F/M (therefore, less land space) and perform much better from a BOD removal-sludge handling standpoint than the air system. The oxygen requirements are slightly higher for the pure oxygen system, but the sludge production was approximately the same. The pure oxygen system provided better stability.

A.4 Paper No. 48

This paper addresses the analytical capabilities of measurement of oil and grease in petrochemical wastewaters and presents the performance of the various technologies for removing these materials. The paper discussed sampling techniques, including collection techniques to deal with stratification in the sewer and handling techniques to avoid contamination by oil from hands in low-level samples.

Tests were conducted using 31 laboratories and statistical correlations of these results were provided. The Freon extraction technique was specified and data from three labs were eliminated because the statistically acceptable range was exceeded. Data from the remaining 28 labs were reported and results correlated to evaluate the analytical reliability and variability among the samples. The results from the Freon extraction-infrared method were considered less variable than those results using Freon extraction-gravimetric techniques. The absolute value from the infrared technique may be in error because of the standard used. It was concluded that significant variations in yield exist between detection methods which result in a high degree of variability in the analysis. The analytical variance as a function of concentration indicates more significance than concentrations less than 10 mg/ℓ.

The review of treatment technology for oil and grease removal from petroleum wastewaters indicated that biological treatment, when well designed and well operated with adequate pretreatment, can produce average effluent oil and grease levels from 3 to 12 mg/ℓ on a 50 percent probability basis with high concentrations in the range of 20 to 60 gm/ℓ (98 percent probability). The addition of post-filtration to biological systems lowered the average value in the range of 6 to 7 mg/ℓ on a 50 percent basis and 20 to 30 mg/ℓ on a 98 percent probability. The observed oil and grease removal from two activated carbon adsorption facilities treating refinery wastewater was comparable only to biological treatment technology. Concentrations in the range of 1.7 to 10 mg/ℓ of oil and grease have been demonstrated in pilot-scale tests using activated carbon but in the United States there are no operating facilities on petroleum refining industrial wastewaters which confirm these results.

B. Prepared Discussions

B.1 A formal discussor cited the lack of an accurate design basis since literature values were used for the catalytic oxidation and the bio-filtration system. He said the comparison was good with the results probably applicable only to developing countries since much land and continuous sunlight was needed.

B.2 The discussion was brief and the discusser stated that 1) yeast production must be feasible with most wastewaters to date; 2) the separation of the yeast is difficult and the effluent still required additional treatment; 3) it was more feasible to produce protein on a commercial agricultural basis; and 4) additional modeling should be done with the data provided by the authors.

B.3 The discusser indicated that more in-plant work should be explored in pulp and paper mills; for example, the Rapson system which employs a titanium-clad reactor for recycle of streams to control the sodium chloride level. The discusser indicated that oxygen does look good, but that some data in the past have been misleading and careful consideration should be given to all cost data before the final decision is made.

B.4 The discusser agreed that analytical standards are practically impossible to establish presently because of the analytical variability in the method used. It was also agreed that biological treatment provides a level of treatment which is just as acceptable as that from the physical-chemical treatment with petroleum wastewaters.

C. Floor Discussion

C.1 Questions were raised on the design and operation of a bio-filter and the fact that the design of the bio-filter and catalytic oxidation were taken from literature.

C.2 There were no questions from the floor.

C.3 The floor discussion clarified the reference to UNOX as the oxygen system. UNOX was not the only oxygen system examined; however, UNOX personnel had worked closely with the investigators and the authors referred to UNOX and pure oxygen interchangeably. It was pointed out that the fiber content was composed of short fibers in the mill.

C.4 Questions were asked from the floor concerning the use of Freon instead of hexane as the solvent in the oil and grease analysis. It was stated that Freon had been selected by EPA because it offers a safer chemical to use in the laboratory. Other questions arose concerning the use of analytical techniques to distinguish between oils of vegetable and animal origin as compared to those oils of mineral origin. The author stated that he had had no experience with this. I mentioned that I had had some experience and that I was under the impression that there was not a readily available technique to distinguish between oils and greases of vegetable and animal origin and those of mineral origin and that EPA had been examining this difference. However, the basis of distinguishing between those oils and greases of different origins was primarily based on the production methods of a specific industry. For example, those industries which make edible oils should only have oils and greases of vegetable and animal origin in their wastewaters unless they had pump leaks which might leak mineral oils, used for lubricants, into the sewer. This could generally be checked on a case-by-case basis.

D. Other Observations and Comments

D.1 The catalytic oxidation system and bio-filtration system would probably only be applicable in the United States as pretreatment ahead of municipal discharge or pretreatment of some other aerobic biological process. In this case, the bio-filter would serve as a roughing device and the catalytic oxidation system would be used only for highly concentrated streams. The cost data seemed accurate, but I do not feel that they included all of the personnel costs. The bio-filter design was probably not optimized and was selected from literature where one or two pilot cases were examined. The most accurate data available were for the anaerobic lagoon; however, it was not modeled and sufficient data were not presented in order to determine its performance on a seasonal basis. No nitrogen data were presented other than influent, which is unfortunate.

D.2 There was quite a bit of interest in single-cell protein production. However, most people agreed that at the present it was not feasible on a commercial basis; the effluent organic concentration was too high and still required additional treatment, and protein can be produced cheaper from an agricultural basis. A considerable amount of the data presented could be used to generate models to predict anaerobic treatment of high-strength organic wastewaters.

D.3 Further discussion showed agreement that the oxygen system appears good for the pulp and paper industry and that a good job had been done on correlating the data. Additional correlation may have produced more conclusive results.

D.4 Serious doubts were raised by the paper concerning the measurement and analytical techniques of oils and greases. This problem is even more serious with industries who use vegetable and animal oils. There is a great need for more accepted methods, which may have to be developed by EPA, to distinguish between oils and greases of vegetables and animal, and mineral origin. Also, there needs to be either a very reliable, accurate technique for measurement of oil and greases, or the permits should incorporate the statistical variability which has been proven for this test.

IV. CRITIQUE OF SESSION

Of the four papers presented in this section, the following comments are offered. Papers No. 39 and 42 were not research oriented studies and only reported abbreviated results. No. 39 compared three systems, but only presented data on one system. Additional data should have been provided on the system presented. This paper has very limited application to the United States.

Paper No. 42 was not a research study and does not apply to the United States but to developing countries. However, some good data were presented regarding anaerobic ponds. These data could be analyzed to generate or confirm design models for anaerobic treatment of high strength wastes.

Papers No. 45 and 48 were very good and highly attended by top caliber individuals in the profession. Although these papers were not research in the true sense, they did confirm other data which had been previously published and presented. Significant correlation of these data established several key points which I thought were important to situations in the United States.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Since no papers were truly research oriented, it was difficult to delineate definite research needs. The data of Paper No. 45 could possibly be correlated better to give a more acceptable comparison of air and pure oxygen. This paper, along with other results I have seen, gives a strong case for the use of pure oxygen in the pulp and paper industry.

Paper No. 48 (oil and grease) definitely stressed the need for improving analytical procedures. Also, emphasis was placed on the fact that physical-chemical treatment is not as definitive as EPA has led many to believe. It should be noted that a well operated biological system may satisfy the requirements for BATEA with appropriate pretreatment such as filtration.

I. SESSION

A. Theme of Session: Monitoring of Waste Discharges

B. Papers Presented:

51. Pollution Control Regulations and Monitoring Technology: A Review of Research and Development from the Pulp and Paper Industry.
D. V. Ellis (Canada)

54. Biomonitoring with Fish: An Aid to Industrial Effluent and Surface Water Quality Control.
W. S. G. Morgan (South Africa)

57. The Use of Ozone Induced Chemiluminescence in Water Quality Monitoring.
V. A. Garten, R. B. Head, R. McNeill, J. M. Overbeek (Australia)

II. REVIEWER

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III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 51

The paper by Mr. Derek V. Ellis was an excellent contribution in describing the pollution control procedures applicable to the pulp and paper industry in British Columbia, Canada.

The data base in the paper came from monitoring results of 11 coastal pulp and paper mills and one large sawmill in British Columbia. Experimental procedures were presented and discussed for monitoring within the "zone of influence" of these outfalls. This zone included the three-dimensional space in which the discharge can be shown as present or as having an effect on the ecosystem. A series of monitoring tests, conducted within the zone, were presented and critically analyzed by the author. These data were used in making an appraisal of the marine water receiving area. Depending upon the magnitude of the pollutant's impact, only one routine procedure or all of the procedures may be required to appraise the effect of the pollutants on the environment.

The monitoring procedures are useful in determining industrial compliance when the discharge regulations are so worded that compliance or non-compliance can be demonstrated by single samples from test and control stations for one or more parameters analyzable by the discharger's process control laboratory.

A.2 Paper No. 54

This paper presented the details of a rapid electronic biological automonitoring system which utilized the fact that fish opercular rhythms increase under toxic conditions. Field application of the system also has the ability of controlling toxic industrial discharges. The details in the paper dealt almost entirely with the how, why, and where of using this device in actual continuous monitoring situations.

The author concluded that the response limit of fish sensors lies between 5 and 10 percent of the 48-hour lethal limit. He believed this respiratory response of fish is a reliable parameter for use in biological automonitoring systems. The monitor enables an industry to take immediate remedial action should the toxicity of its waste increase.

A.3 Paper No. 57

The paper was presented by Mr. R. McNeill of CSIRO-Melbourne, Australia. The paper dealt with a device for water quality monitoring which utilized the almost instantaneous chemiluminescent reaction of certain readily oxidizable, organic (and inorganic) materials with ozone. This phenomenon is due to the fact that ozone can react as either a 1,3-dipole, an electrophile, or a nucleophile. This makes it possible to distinguish between different chemical groups present in a mixed substrate.

Generally, the recorded photon count is proportional with the concentration of certain substances in the water. However, some anomalies exist. For example, a pure solution of sucrose gives inconclusive results. Also, the measure is pH and temperature sensitive.

B. Prepared Discussions

B.1 Mr. Lars Hall of Sweden noted that the paper indicated other ways of controlling pollution exist and that the British Columbia Pollution Control Act indicates that pollution should not interfere with the water's use. However, the paper failed to recognize that in-plant control is the real place where emphasis should begin in the protection of receiving waters. This is the better approach to the solution of the problem.

Thus, it was emphasized in the discussion that the implementation of the best technical solutions that were economically achievable do not relate solely to the state of the receiving waters as might be implied in Mr. Ellis' paper. Instead, the solutions should consider how the production process itself could be improved by in-plant control, thereby minimizing the development of a potential receiving water problem. Thus, it may not be necessary to use the maximum resources of the receiving water for waste assimilation. Long term effects by successive discharges can be prevented by the in-plant approach to the problem's solution. Only after the worst in-plant problems have been corrected by maximum in-plant controls is it proper to use receiving water quality as the determinant in establishing a base for further pollution control requirements.

The principles proposed by Dr. Ellis are in agreement with modern Swedish thinking with regard to the receiving water question. This should be limited to a few key water quality parameters within a geographically restricted area for reasons related to the cost of monitoring these waters. The studies within the zone of influence should be conducted over a long period of time with each study conducted at approximately three-year intervals to establish long term effects. Sea bed effects are most important as a part of this type of study.

8.2 Dr. John Cairns of the United States noted that Morgan's research on biomonitoring is among the best for the field. Dr. Cairns suggested this system may be more useful for the less skilled operators if the threshold response were replaced by a probability of harm estimate. In this manner the readout would be like a weather report, i.e., 20 percent chance of rain (toxic conditions) being experienced today. This may prevent possible false alarm signals from causing a needlessly expensive plant shutdown.

Dr. Cairns emphasized that some back-up is needed in that an in-plant biological monitoring system should never be the sole means of evaluating the effects of a waste discharge upon a complex aquatic ecosystem. We cannot afford to ignore the limitations of even the best methodology. This limitation might be partially offset by using species of several trophic levels in the system.

8.3 Mr. Cyril Gomella of France noted that for the moment this method is not useful for routine laboratory analysis carried out by medium level staff. The paper does not explain what method is applied to determine the rate of spontaneous decomposition of ozone and the correction to be applied for exact determination of actual ozone consumption. Also, no data are given regarding the cost of this device.

It was acknowledged in the author's paper that chemiluminescence can and cannot be induced by ozonation. In some cases (low temperature and low concentration, for example) many chemical bodies escape from ozone attack. For these and other reasons, it is not possible to place a general and absolute significance on the induced chemiluminescence test.

The test may have some value when bodies are polluted with specific materials that do have a good chemiluminescence response to ozone. This might include petrochemical effluents, pulp mill effluents and natural waters with a high content of humic acids. At this time this instrument is suited for research laboratory work and is not yet adapted for routine laboratory or field work.

C. Floor Discussions

C.1 The following significant observations and comments were made during the floor discussion. Dr. Michael Kingsfort (NZ) commented on the operation of pulp mills in his country. He mentioned a problem of inefficient operation of chlorine cells. This resulted in a high level of mercury in fish taken from the lake. Another problem is foam released below a hydrostation tailrace. It was implied that these are problems best prevented by in-plant control and that they should never get to the point where a receiving water investigation is required to detect the problem.

Peter Higgins (Canada) emphasized that Canadian regulations under the Federal Fisheries Act also place emphasis on in-plant controls and that this may not have been sufficiently emphasized in the formal paper. Every mill in Canada is basically required to meet the same minimum level of controls.

Mr. Vordman (UK) spoke to the problems of zinc in pulp effluents. The speaker indicated this is used in groundwood bleaching and present technology has resulted in boron compounds replacing zinc as a bleaching agent. Again, the comments from the floor emphasized the significance of in-plant controls as opposed to subsequent monitoring of recipient waters.

C.2 The following significant observations and comments were made during the floor discussions. Mr. Morgan emphasized that in South Africa operators do not like to make decisions and hence the "probability of toxicity concept" is not applicable since the evaluation is always made by the responsible person in charge.

The tendency of fish biomonitoring research is toward breathing rate monitoring and away from the cough rate monitoring system that has been proposed earlier by several researchers. This is because some fish cough and some fish do not cough. Thus, coughing is not a reliable method of monitoring. The fish in Dr. Morgan's system were used for no more than three months (to prevent conditioned responses). Once a fish responded, that fish was never used again since the future response of the fish was then not predictable.

If the system is used in a field application, the surrounding food must be filtered out of the water. Feeding the fish interferes with the fish response to the biomonitoring system. Therefore the researcher must be careful to not monitor the fish during the feeding period.

C.3 The claim that a two or three percent instrument accuracy existed was questioned from the floor and the author explained this was based on analysis laboratory samples of pure compounds. The device is not claimed to be a substitute for TOC or other basic analytical parameters. The effect of possible interfering compounds such as chlorides has not been investigated.

D. Other Observations and Comments

In Dr. Ellis' response, he emphasized that the monitoring work he describes in the paper points to the need for impact assessments being made on new plants before they are built. Thus, this may result in the new plant's implementing improved production technology as a preventative measure and thereby preserve the receiving water area. Dr. Ellis believed that in-plant technology and recipient monitoring have considerable interplay in the realization of industrial pollution control.

The paper on biomonitoring was well received by the session attendees. It pointed out significant advances that are being made in understanding and applying the knowledge of biomonitoring of fish. An additional useful aspect of these developments in biomonitoring is that this information can be a useful indicator tool to signal industrial plant operators and managers of deficiencies which may be unknowingly occurring in the production process, thereby needlessly releasing toxic elements. Biomonitoring of fish can thus become a tool to improve the efficiency of production process operations within the industrial plant.

The author (Paper No. 57) stated in his presentation that he would be receptive to suggestions from the conference attendees on means to put this device to a practical use. This appears to be the situation where an idea has been developed and is now in search of a purpose for which it can be usefully applied.

IV CRITIQUE OF SESSION

I believe the floor discussion of Paper No. 51 indicated to the more aware conference attendees that today throughout the world the problems of industrial pollution control are increasingly shifting from (a) the traditional environmental engineering approach of studying the effects of a problem and then looking for a traditional solution to (b) attacking the problem of pollution at its point of origin within the production process and in this manner reducing the pollutant discharges to the maximum levels with available technology. This approach thereafter requires further external treatment based on an evaluation of the recipients assimilative resources.

In the case of new factories, the pool of knowledge related to effects of pollutant discharges on the recipients is a useful tool in evaluating where the new factory should be located. Increasingly today the decision process on plant location is also supplemented by social-economic evaluations which must go hand in hand with environmental evaluations.

The paper by Mr. Ellis was well prepared. Its greatest usefulness at this conference may have been to motivate the attendees to recognize that a monitoring program can bring about change which may prevent pollutants from ever being originally released to the recipient from the industrial production process.

Paper No. 54 was excellently prepared and the discusser, Dr. Cairns, was knowledgeable of the subject material. The discussion was therefore excellent and concise. The paper pointed out many of the most recent trends, developments, and limitations of biomonitoring with fish. The paper and review elicited thoughtful response from the audience.

Paper No. 57 described a research instrument that is still in the developmental stage. Before this instrument can find widespread use, it will be necessary to further define its practical applications that were broadly proposed in the paper. The attendees generally recognized the limitations which exist with the present state of development of this concept and instrument.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The paper by Ellis and its discussion pointed to a need that research on industrial pollution problems in the United States should be directed to understanding how and why pollutants originate in the production process. This knowledge is essential in order for implementation of the most cost effective solutions to the problem.

Paper No. 54 was an excellent paper which presented an example of water pollution research effectively applied as a practical tool. Application of this technology will most likely result in many industrial dischargers becoming more cognizant of toxic material in their wastewater discharges. This in turn may lead to a further clean up of toxic discharges from the production process itself.

This paper (No. 57) described instrumentation which is presently in an early stage of development. Its immediate value in the United States may be limited. The need and usefulness of the concept should be further evaluated before a parallel interest of development is justified in the United States.

I. SESSION

A. Theme of Session: Water Resources Quality Management

B. Papers Presented: Workshop - Water Resources Quality Mangement
Convener: W. K. Lewis
Speakers: P. M. Higgins (Canada), L. B. Wood (UK), H. Schmidt (Fed. Rep. Germany), M. R. Henzen (South America)

II. REVIEWER

A. Name: Robert A. Canham

B. Position and Affiliation: Executive Secretary, Water Pollution Control Federation
2626 Pennsylvania Avenue, N.W.
Warhington, D.C.

III. REVIEW OF SESSION

A. Formal Papers

A.1 The speaker from Canada, Higgins, separated his remarks into the following subjects:

1. Canada's soft water lake systems, their low buffering capacity and resultant sensitivity to SO_2 and nutrient loading.

2. Lake eutrophication and its acceleration by excess nutrients.

3. Man made lakes as they are affected by previous control decisions.

4. Possible conflict and principles in the relationship between water resources management authorities and those required to comply with water quality management decisions.

The speaker discussed in broad terms the circumstances in Canada whereby there are many areas where the lakes receive acid from sulfides from the natural mineral sources. The resultant low pH of the water does not encourage vegetative growth and is not an attractive environment for fish.

There was no discussion of suggested solutions nor a program that is dealing with the problem. As a result management of these water resources was not discussed. Problems of eutrophication, particularly in the Great Lakes, were discussed. Management of the problem was not discussed except to indicate that some sort of a concerted effort is needed.

The well documented circumstances of DO and waste assimilative capacity in impoundments were discussed but no detailed discussion of management techniques was included. Beyond commenting on the fact that there are philosophical conflicts between those who view impoundments for different uses and the comment that in Canada regulations for industrial discharges are developed cooperatively with industry, the author did not discuss management alternatives and merely wondered whether the cooperative approach will work.

A.2 The speaker from the United Kingdom, Wood, discussed in general terms a textbook approach to management of water resources quality and then discussed some of the major problems facing the newly organized regional water authorities in U.K. His emphasis was on the financial crisis that has confronted Britain in recent years and how it is affecting the activities of the regional water authorities.

The author proposed solutions to the problem and it is unlikely that many would disagree with the reasoning. However, a careful look at the proposed solutions suggests that in each enumerated solution there would be enormous cost involved. As a result it appears that the solutions offered will not be attained because of the financial problems and that, therefore, there will be business as usual.

A.3 The speaker from West Germany, Schmidt, chose ground water as his subject. Since ground water is and will continue to be a major source of water in Germany there is a high priority set on its management. The basic reason for this is that about 2/3 of the water sources now is from ground water and the demand is predicted to increase 50 percent by the year 2000.

As the other speakers did, this author discussed a series of reasons why additional work is needed to protect the ground water but he went somewhat further to discuss some of the ways that the government and the technical community have tried to attack the problem. Mostly these have been regulations and guidelines made possible by a national law on the water budget. The regulations provide some uniformity and limits on activities that jeopardize the quantity and quality of ground water. However, there is scant reference to any results of the relative degree of effectiveness of the law and its regulations. The author did refer to a five-year plan (1977-81) of the European Communities that places high priorities on the protection of ground water but without sufficient detail to understand the plan.

A.4 The fourth speaker (Henzen), who was from South Africa, discussed the problems of acid mine drainage. Since South Africa is a major producer of metals for the world market it is natural to assume that acid mine drainage is a primary problem. Since South Africa is a water-short country this is even more important.

He referred to the Water Act of 1956 which sets national water quality standards for water used by industry but pointed out that the standards do not apply to underground water pumped from mines or runoff from mine dumps. Regulations were developed in 1976 for these waters.

The author discussed in considerable detail the various problems of acid mine drainage including data and he discussed some solutions. However, the status of the work to solve the problems is mostly in the research stage and there is little evidence of full-scale results of applying various theories. In fact, most of the solutions discussed were theoretical.

B. Prepared Discussions

There were no prepared discussions in this workshop. All discussion was handled by the Chairman through the selection of questions or statements made on cards submitted by the audience during the session.

C. Floor Discussions

There was an active discussion from the floor; some of the more pertinent dialog is mentioned briefly below.

It was pointed out that none of the speakers included socio-economic matters as a part of the presentation and that these are important in a management program.

It was brought out that in Germany a new discharge law sets a schedule of payments for pollution in different degrees and that there are controls imposed on quantities of discharge as well as quality.

The Canadian speaker emphasized the difficulties with imposing requirements on old, existing industries vs. the lesser problems of the same requirements with new plants. Canada requires a comprehensive assessment of all new chemicals.

Implementation problems in the new regional water authorities in the U.K. were discussed and it was apparent that some of the requirements or manifestations are similar to current experience in the U.S. The requirement for public disclosure of all data has led the Thames Authority to a different stream classification concept which identifies priorities. Also it was stated that in the U.K. the policy is that the polluter pays (and therefore is allowed to discharge some degree of pollution) but that toxics must be removed.

In Germany it was revealed that the new requirements for protecting ground water include such details as diversion of surface water during construction; that there is some effect on vegetation from ground water withdrawal; that problems of oil transport by pipeline, truck, rail, etc. have not been solved; and that there is no solution in sight for ground water that already is polluted.

Relative to acid mine drainage, the speaker from South Africa responded to questions in several areas by saying that the mine owner is responsible for the water on his site only, that the government monitors surface water that flows through mine areas, that there is no Federal subsidy for construction of corrective systems for gold or coal mines, and that there are requirements for treatment of process water in construction works when the water is supplied from the outside.

The Chairman summarized the session by pointing out that effective management can only be carried out with proper organizational framework and with cooperation, that both short- and long-term objectives must be incorporated, that adequate financing is necessary, that practical legislation is needed, and that in the development and implementation there is a need for more research.

IV. CRITIQUE OF SESSION

The philosophy behind the planning of this session may have been reasonable but the results left the listener far short of high value. There was no cohesion in the subject matter and none developed in the presentations and very little in the discussion.

The idea of having speakers from four countries was excellent but apparently the planning specified that the four subjects also were to be different. It would have been much more useful to ask four speakers from different countries to discuss the management aspects of any one of the subjects, i.e., lakes and impoundment, rivers and estuaries, acid mine drainage, or ground water. There was more information exchanged in the discussion period than in the presentation, even though the discussion time was short.

A major criticism was that the subject of the session, Water Resources Quality Mangement, really was not covered if the listener expected to learn something about effectiveness of management. The speakers dicusssed at length the problems that need to be solved through management techniques but left the listener wondering whether any progress has been made or whether there has been any evaluation of the effectiveness of the management structures. In some instances there was no discussion of the strategy being used and in others the discussion was only about the theoretical management needs.

The speakers in general provided reasonable background on the problems and this is necessary, but it would have been much more useful if more attention had been given to the methods and measures of effectiveness of the work underway to provide solutions to the problems.

One positive aspect of a session like this is that it identifies individuals throughout the world who can be called on through continuing communications to discuss more details in the areas of their expertise.

It was obvious that there was strong interest in the session as measured by the number who attended, the high percentage who stayed throughout, and the number of questions. However, it is felt that the value of the session was far less than it could have been if a different set of specifications had been given to the speakers.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

This session, not being on research, has a different set of values to American researchers but nevertheless has some.

The speaker from South Africa discussed research projects underway that are aimed at dealing with the problems of his subject, acid mine drainage. However, he is a research individual and the contents of his paper are to be expected. The other speakers are not research people and their papers reflected this fact.

The Chairman correctly included a comment that more research is needed to deal with the problems of water quality management but that was not the thrust of the session. As a result of these factors this workshop had limited value to American researchers *per se*. If the results of research were matched with earlier objectives and programs in water quality management, the session would have been more useful to the U.S. research community.

It is questionable whether the program for this conference should include workshops with subjects like this since they do not fit the original objectives of the sponsoring organizations.

I. SESSION

A. Theme of Session: Toxicity of Industrial Wastes

B. Papers Presented: 58. Development of a Rapid Fish Toxicity Test Utilizing a Freeze Concentration Technique for Routine Petroleum Refinery Wastewater Monitoring.
E. C. Birchard (Canada)

61. Compounds Toxic to Fish in Pulp Mill Waste Streams.
J. M. Leach, A. N. Thakore (Canada)

II. REVIEWER

A. Name: Richard D. Pomeroy

B. Position and Affiliation: Consultant for Special Projects
Jacobs Engineering Co.
Pasadena, CA

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 58

Three of the papers, Nos. 58, 61 and 70, dealt with various aspects of toxicity tests by bioassays, reflecting an awareness that more needs to be known about this widely-used method for effluent monitoring. The particular paper examined in this review is No. 58, authored by E. C. Birchard, but reference will be made also to No. 61 because of its pertinence in an overall view of the subject.

The object of the research reported in Paper No. 58 was to find a way to obtain indications of the toxicity of wastewater from oil refineries and petrochemical plants without waiting the full time specified for the standard test. In effect, it is desired to obtain in a few hours a test equivalent to a 24-hr TL-50 result and, in a similarly shortened time, to obtain an estimate of the probable 96-hr result. The method selected for investigation in this research is concentration of the toxicants into a smaller volume before accelerating the response to any toxicants that may be present.

A procedure for concentrating the toxicants in a wastewater should, insofar as possible, remove water from the solution, leaving the dissolved toxicants unaltered except as to concentration. There is no way to accomplish this concentrating effect that will assure that the ideal objective can be attained. Concentration by freezing will trap some portion of the toxicants in the ice. Removing part of the water by evaporating it is likely to vaporize some of the organic components as well as the water. A reverse osmosis membrane has the disadvantage that most solutes, especially non-polar ones, will pass through it to a significant extent. Furthermore, any concentrating technique may encounter boundaries imposed by solubility relationships.

Mr. Birchard concluded that freezing out part of the water held the best hope for getting useful results.

A.2 Paper No. 61

A question naturally arises as to whether chemical tests might not be an alternate way to get a prompt indication of toxicity. This question came to the fore in Paper No. 61. A remarkable piece of research was there described in which a high degree of analytical skill was shown in determining toxic components in 124 wastewater samples from wood pulping operations. Twenty-six complex organic compounds, including resin acids, fatty acids, terpene alcohols, juvenile insect hormones, and chlorinated organics, were identified and quantified. Furthermore, toxicites of the wastewaters were quite closely predicted from the analyses and the known toxicities of the components. Despite the success of that research, it does not presently appear that the chemical method could replace the bioassay for the pulp industry, because a complete chemical analysis would take far more time and effort than the bioassay. It is possible that proximate analyses for certain classes of compounds, or the determination of a few of the most important of the toxicants, would give results that provide adequate correlation with overall toxicity. Insofar as analytical results can be used this way, they afford best means for setting sub-lethal standards of toxicity.

B, C & D. Discussions

The prepared discussion was presented by J. Cairns (US). The review of all of the discussions, including those from the floor, and also information from other papers and arising from this writer's background, are presented in an arrangement based upon subject matter rather than upon participants.

When wastewater from one Canadian refinery was concentrated by freezing to one-fifth of the original volume, the concentrate contained from 70 to 79 percent of the ammonium, sodium, chloride, total organic carbon, and total solids. Thus, the concentration ratios for these materials were relatively uniform at between 3.5 and 4. Zinc recovery, however, was only about 50 percent. When another refinery wastewater was spiked with solutions of Cu, monovalent Hg, Ni, Pb, Zn and trivalent Cr, the results were quite erratic. This is not necessarily a matter of concern with refinery wastewaters since these metals are rarely present in significant amounts in these wastes, except for the occasional presence of hexavalent chromium from cooling towers.

Using wastewaters from four refineries in Canada, comparisons were made of results by two laboratories for the standard 24-hr static tests and also results from the 96-hr flow-through tests, survival times with freeze-concentrated samples, and survival times with samples that had been freeze-concentrated and then reconstituted. A sample from a fifth refinery was tested only by the 96-hr test and by determining survival times after freeze-concentrating. Fish survival times in the four unaltered samples ranged from about 15 min to 800 min.

Fish survived an average of 60 percent longer in the reconstituted samples, showing that some of the toxicity was lost in the process of freezing and then reconstituting the sample from the ice and the concentrate.

Regression equations were developed for correlating by pairs the results by different methods or laboratories; five such equations were developed. One discusser criticized the method of calculating the equations. It seems that a more serious criticism is the paucity of the data. Only four samples were tested by all five methods and a sample from a fifth refinery was tested by two methods. Four or five pairs of x-y values, particularly when the results are quite scattered, as they were in these tests, do not afford a very good basis for conclusions. The correlation equations are rather trivial, anyway.

The author estimates that a bioassay after employing the freeze-concentration technique will give in five hours about the same result as will be found in the standard 24-hr test, and in 13 hours the result will be about the same as in the standard 96-hr test.

In answer to a question about the nature of the toxicants in the wastewaters, Mr. Birchard said that the principal ones known to be present are ammonium, HCN, and phenols.

More work on identification of toxicants in the refinery wastewaters should be undertaken. The task should be considerably easier than with the wood pulping wastes.

It will probably be agreed by all workers in this field that toxicity monitoring by bioassays will continue to be necessary as a catch-all method for the unknowns. It is probable, however, that greater attention to analytical tests might often accomplish the objectives sought in the research reported in Paper No. 58.

In answer to a question, Mr. Birchard agreed that the applicability of the freeze-concentration technique could not be assumed for any type of waste other than the wastes for which it was tested. He does not propose its general use, but showed that it can be serviceable to providing the refinery management with an early warning of excessive toxicity in the discharged wastes. It is inferred that it may prove similarly useful for other industries as well.

It was pointed out by one discusser that from the time of sampling until the time of obtaining a result from the freeze concentrated sample would be about eight hours because the time for the preparative manipulations must be included.

The importance of an early warning technique is related to the variability of the effluent. One paper of the conference (No. 31) dealt mathematically with the subject of variability. Whatever the nature of these relationships, it is obvious that if the wastewater passes through completely or partially mixed basins, effluent variability will diminish as the retention time increases. If a refinery uses large ponds for treatment, as some do, with detention times of several days, the rate of change of effluent quality is slow enough so that accelerated bioassay tests would not be very important. Long retention times should be encouraged as a means to minimize the danger of toxic discharges.

IV. CRITIQUE OF SESSION

The papers were critiqued in the Discussion Section.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The subject of detecting unacceptable discharges is tied in with the general question of enforcement of standards. It is not particularly effective for a pollution control agency to set an effluent toxicity limitation based upon a concentration that is expected 1 or 2 percent of the time, or to tell an industry that it is allowed a certain number of violations per year. This is a contradiction in terms. An industry does not like to be recorded as having been in violation if it has in fact done only what is allowed.

It is appropriate that there be effluent limitations that the industry should never exceed. More important, the industry should show that it has provided the means to prevent such discharges. It has long been required that a refinery provide dikes around tank farms as security against massive oil spills. Diked areas or other kinds of basins should be provided for the diversion of unacceptable effluents so that the refinery (or other industry) can continue to operate during a period when the treatment plant effluent is unacceptable for discharge. This is not a part of the subject matter of Paper 58, but it shows a use to which an accelerated bioassay test might be put.

It is not expected that the concentration technique for accelerated bioassays will be widely applicable, but it is useful to know that the technique has been examined and that it may prove useful at least in the petroleum refining industry.

I. SESSION

A. Theme of Session: Stream Oxygen Balance and Bioassays

B. Papers Presented: 64. Nitrification in Free-Flowing Streams.
F. F. Lopez-Bernal, P. A. Krenkel,
R. J. Ruane (USA)

67. Consideration of the Efficiency of
Attached Organisms in the Simulation of
Self-Purification and Oxygenation Capacity
of Flowing Waters.
P. Wolf (Germany)

70. Comparison of Semi-Continuous and
Continuous Flow Bioassays.
J. H. Reynolds, E. J. Middlebrooks,
D. Porcella, W. J. Grenney (USA)

II. REVIEWER

A. Name: N. Bruce Hanes

B. Position and Affiliation: Professor and Chairman, Department
of Civil Engineering
Tufts University
Medford, Massachusetts

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 64

The paper entitled "Nitrification in Free-Flowing Streams" represented a practical approach for predicting dissolved oxygen levels in rivers and streams where nitrification is a significant factor. It should be noted that the consideration of nitrification in deriving dissolved oxygen levels in our waterways has increased in importance as the United States water pollution control program has made progress in reducing the carbonaceous waste material in our streams. The authors cited recent examples where nitrogenous oxygen demand was actually greater than that of carbonaceous material. This reviewer has also personally experienced similar conditions in recent stream survey work. Also of interest was the evidence presented that attached organisms play an important role in the nitrification process.

The authors stressed that the nitrification model developed in their presentation was "descriptive" rather than "predictive," thus requiring field data collected under conditions similar to those under which the model is applied. The nitrification process was represented in the model by zero order and/or first order reaction equations.

Procedures for the development of both equations were presented. In this study K_{nr} represented the stream nitrogenous BOD distribution coefficient that included removal of nitrogenous oxygen demand by oxidation plus the effects of equilibration, cell synthesis and other factors while K_n represented the removal of nitrogenous oxygen demand by oxidation only. The authors gave the following typical values for Southern rivers:

K_{nr}	K_n[1] (NO_3)	K_n[2] (NH_4)
4.1-1.33	1.68-0.50	0.37-0.65

[1] based on increase in nitrate nitrogen
[2] based on decrease in ammonium nitrogen

A.2 Paper No. 67

This paper entitled "Consideration of the Efficiency of Attached Organisms in the Simulation of Self-Purification and Oxygenation Capacity of Flowing Waters" represented a different approach for the prediction of dissolved oxygen levels in both natural and man-made waterways. The author developed a model that is dependent on oxygen removal by suspended and attached organisms. He noted that in the case of shallow turbulent streams, the effect of oxygen removal by attached organisms cannot be ignored. The rate of oxygen removal by the attached organisms is estimated from data obtained from rotating bio-disks treating domestic sewage as well as the depth and roughness of the stream under study. The rate of oxygen removal by suspended organisms is estimated on the basis of the kinetics of domestic sewage which was found to differ for mechanically purified and biologically purified wastewaters. The author has applied the model to 10 different waterways which included a 1000 m model channel, small mountain streams, larger streams and finally the lower reaches of the Rhine River all with good results. The unique aspect of this model is its requirement for a minimum of actual data from a particular stream.

A.3 Paper No. 70

The paper entitled "Comparison of Semi-Continuous and Continuous Flow Bioassays" presented the theory relating semi-continuous flow cultures to continuous flow cultures as well as evaluating results obtained from a toxicity bioassay study employing both techniques. The semi-continuous flow culture technique is an approximation of the standard continuous flow system and may prove useful as a screening technique of toxic substances. Thus a comparison of the two systems is the first step that must be taken in determining the value of the development of a standard semi-continuous flow culture procedure. An evaluation of the basic theory of the two systems suggests that one could expect comparable results. A comparison of the actual data indicated that competitive inhibition constants obtained from semi-continuous flow cultures indicated less phenol toxicity to the algae *Selenastrum capricornutum* than inhibitor constants obtained from continuous flow cultures. The authors suggest that this difference may be a function of cell growth rate in comparison to the time interval between withdrawals.

B. Prepared Discussions

B.1 The prepared discussion for Paper No. 64 was presented by J. Garland (United Kingdom). He conceded that the nitrification process appeared to be adequately described by zero order and/or first order reaction equations but stressed that in theory the process was actually an autocatalytic growth reaction. Mr. Garland expressed disappointment that the authors had not attacked the nitrogen balance directly but acknowledged that it is a most difficult problem. He further agreed that nitrification in streams is primarily a benthic function as a result of some of his observations. Finally, Mr. Garland complimented the authors on performing a useful service by calling attention to the nitrification problem in waterways and expressed the wish that the paper would stimulate further work on the problem.

B.2 Mr. K. Poppinghaus (Germany) led the discussion on Paper No. 67. He was critical of the paper and questioned if the model presented could adequately describe the complex interactions that influence the dissolved oxygen levels in a stream. For example, he was concerned with the lack of a factor in the model to account for reaeration from either the surface or aquatic plants. In addition, he was concerned with the problem of nitrification and the fact it was not considered in the model. In summary, Mr. Poppinghaus questioned if the model, as presented, would have general application to different waterways.

B.3 Ms. D. Brockett (New Zealand) presented the prepared discussion for Paper No. 70. In general, she concurred with the authors and expressed the opinion that it was a good paper. Ms. Brockett also suggested that the semi-continuous flow culture technique may prove to be a good screening technique for toxic substances. She encouraged other researchers to work on learning more about the technique so that either a standard method could be developed or the technique rejected.

C. Floor Discussions

C.1 Paper No. 64 initiated a lively floor discussion. Mr. W. Gujer of Switzerland challenged the authors' failure to develop a "predictive" model for nitrification in streams. He expressed the opinion that while the nitrification process was complex it could be modeled in a "predictive" fashion. Mr. Gujer then proceeded to present a "predictive" model he had developed for a Swiss Stream. Mr. Krenkel responded that the concept presented by Mr. Gujer was desirable for a basic research effort but would not be practicable from an applied point of view. The use of the "predictive" model presented would require considerable background information that would be too costly and time-consuming to obtain in most cases. He further expressed the opinion that the Swiss model presented appeared to be primarily for a specific case. Mr. Gujer acknowledged that the model had been developed for a stream with a high velocity. Mr. Krenkel also agreed that the nitrification process was autocatalytic by nature but practically could not be described in that manner in a complex river situation.

C.2 The theme of the floor discussion of Paper No. 67 questioned the general application of the model to different streams. Mr. W. Gujer of Switzerland requested confirmation that the model had actually been utilized on 10 different streams. Mr. Wolf confirmed its general use but did acknowledge that nitrification and reaeration must be taken into consideration.

C.3 In the discussion of Paper No. 70, Mr. Ullman (West Germany) agreed that the semi-continuous flow culture technique had the advantage of utilizing several reactors for different variables simultaneously. He did express concern, however, with the use of the Michaelis-Menten-Monod equation for the kinetics of the inhibition model. He also was concerned with the use of laboratory bioassay techniques to predict the behavior of toxic elements in the real world. Mr. Ullman ended his remarks with a request for the lighting conditions used in the study. Mr. Reynolds responded that continuous flow bioassays were easier to relate to real world problems, but that if semi-continuous flow bioassays could be understood and adequately described they may prove an excellent alternative. He also defended the kinetics used in this study. He concluded that the lighting conditions were the same as those recommended by EPA, 400 ft candles ± 10 percent of continuous illumination.

D. Other Observations and Comments

This session was the last of the conference which limited the informal discussion of the material which usually occurred following the formal presentation. This reviewer was especially impressed, however, by the excellent attendance of the session (150 participants) considering its position on the program. The seriousness of conference participants was apparent.

IV. CRITIQUE OF SESSION

The session as a whole was excellent and well received by the participants. The discussion leaders were prepared with written comments and raised pertinent questions concerning the work presented. The conference participants had, as a whole, read the pre-prints of the papers and actively took part in the floor discussions. The authors did not read their papers but rather used the time to introduce and expand on the material presented in the printed paper. For example, Mr. Krenkel described how the model had been used by the Tennessee Valley Authority in the U.S., reviewed the analytical procedures and presented typical nitrogenous removal rates for oxygen that did not appear in the paper. While honest questions were raised concerning Paper No. 64, after the discussion, the consensus of the session was positive and it was apparent that the procedure described was ready for use.

Mr. Wolf's model for predicting the oxygen balance in a stream (Paper No. 67) met with considerable skepticism. In his presentation, Mr. Wolf utilized slides of rotating disks, the model 1000 m channel, as well as the river and streams in which the model had been successfully utilized. Nevertheless, at the close of discussion there was the feeling that the model as presented, although original, would not apply in a broad number of cases. Mr. Poppinghaus, who led the discussion, was especially effective in presenting his views.

Mr. Reynolds, in his presentation, briefly outlined Paper No. 70 integrating the material with a series of slides of the laboratory equipment and procedures. Although a few specific items were questioned the paper as a whole was well received. It was the feeling of the conference participants as well as the authors that while considerable work remains to be done with semi-continuous flow bioassays, the results of Paper No. 70 indicate definite promise.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The results of the paper entitled "Nitrification in Free-Flowing Streams" can and should be applied to estimating dissolved oxygen levels in this country's streams. While it is an empirical tool that works, a better understanding of the nitrification process in streams would provide a better tool in the future. It is suggested that basic research into the nitrification process in rivers and streams would prove fruitful in the future.

This reviewer questions the model developed in Paper No. 67. Although the author presented confirmation on two rivers, it should be noted that the actual range of dissolved oxygen values in the rivers that the model was matched with were often in excess of 4 mg/ℓ and in one case was 9 mg/ℓ. The only apparent practical use that this model may have is to make a first estimate of a river's dissolved oxygen profile when a minimum of information is available.

The implementation of the Toxic Substances Act in the USA will require considerable research in the future. While Paper No. 70 does not provide the final answers concerning semi-continuous flow bioassays, it does provide a good basic background for further study. It is now apparent that a quicker and simpler standard technique for screening a large number of toxic materials is needed. This technique appears to show some promise for this type of work.

I. SESSION

A. Theme of Session: Land Treatment

B. Papers Presented: Workshop - Land Treatment.
Convener: A. Wachs
Speakers: C. E. Pound (USA), J. P. Hyman (South America), J. C. Lance (USA), J. B. McPherson (Australia)

II REVIEWER

A. Name: J. C. Lance

B. Position and Affiliation: Research Soil Scientist, U.S. Water Conservation Laboratory
U.S. Department of Agriculture
Phoenix, Arizona

III. Formal Papers

A.1 C. E. Pound (USA) discussed the long-term effects of infiltration of wastewater into soils. He described a rapid infiltration system near Hollister, California, where wastewater has been applied for 30 years. The water was treated in an Imhoff tank in earlier years and now it is treated in an unheated digester before application to flooding basins. The wastewater from a city of about 10,000 people is now applied to 7 ha. The total amount of water applied per year is about 30 m.

The water table depth is at about 20 m, but clay lenses cause a perched water table above that level. About 33 kg/ha/day of N and 17.6 kg/ha/day of P are applied. Preliminary results indicate that nitrogen removal is significant but a quantitative estimate is not yet available. No COD, BOD, or P from the sewage appears to have reached the deep aquifer.

A.2 J. P. Hyman (SA) discussed land disposal of mineralized effluent from pulp and paper mills. He indicated that land treatment is a feasible method for disposal of some pulp and paprr wastes.

A.3 J. C. Lance (USA) discussed nutrient and pathogen removal by rapid and slow infiltration systems for land treatment. Some of the practical problems in managing a high-rate system were discussed, and then nitrogen removal by both rapid and slow infiltration systems was discussed. Experience over the past 10 years with the Flushing Meadows Project showed that high infiltration rates (40 to 60 cm/day) can be maintained by intermittently flooding with cycles of 2 weeks flooding alternated with 1 to 2 weeks drying. These rates could be maintained without clearing the surface when the suspended solids content of the effluent was below 10 mg/ℓ. Soil column experiments showed that infiltration rates with primary effluent could be maintained at a much higher suspended solids level (50 to 150 mg/ℓ). Infiltration was greatly reduced when detention in a pond allowed a buildup of algae in secondary effluent before application in flooding basins.

Most of the BOD, COD, and fecal coliforms were removed at all infiltration rates. No viruses were detected in 400-ℓ samples concentrated from wells at 2-month intervals during one year. Laboratory studies showed that the recharge basin sand has a very high adsorption capacity for viruses.

N and P removal by high-rate systems was discussed in a previous paper by J. C. Lance. It was briefly mentioned that most of the N and P could be removed in a rapid infiltration system by careful management of infiltration rates and flooding and drying cycles. Denitrification is the reaction which must be used for N removal in a high-rate system. Crop removal is the only N removal system which has been quantitatively evaluated for slow-rate of irrigation systems. Thus, only N removal by crop removal can be accurately calculated.

Nitrogen is undoubtedly lost by denitrification but the amount isn't known. Management practices could be developed to increase N removal by denitrification in low-rate systems. Significant amounts of N could be stored in soil organic matter when primary effluent, raw sewage, or cannery plant effluents are applied, but the amount stored when secondary effluent is applied is probably very little. Storage of NH_4-N cation exchange is temporary but important in slowing the movement of N through soils.

A.4 J. P. McPherson (Australia) described the Werribee farm land treatment system in Melbourne. The farm treats sewage from about 1.6 million people at an annual cost of $2.60/person ($3.25 U.S.). Raw sewage is applied by flood irrigation to pasture land during the summer and the grass is grazed by beef cattle and sheep. About 10 cm of sewage is applied every 18 to 20 days, with an average of 105 cm/yr. The water which moves through the soil is collected in drainage ditches and released into Port Phillip Bay. The reduction of BOD, N and P is more than 90 percent.

The land irrigated with raw sewage during the summer is not used during the winter. Instead an overland flow system is used on another area of very slowly permeable soils. The water applied to the overland flow system is first passed through sedimentation tanks. The removal of N is about 60 percent, and P removal is about 35 to 40 percent. BOD removal is more than 90 percent.

The two land treatment systems handle about one-half of the total flow of sewage water entering the Werribee farm system. The remaining half is treated in lagoons. The water passes through a series of lagoons before release into the bay.

Beef cattle are bred on the Werribee farm and sold to help reduce the cost of the system. Sheep are bought in the spring and sold in the fall to complement the beef production system. Every carcass of beef from the Werribee farm is inspected and no health problems have been encountered.

B. Prepared Discussions

These were not used in the Workshop format.

C. Floor Discussions

H. I. Shuval presented information from irrigation systems in Israel showing that crop production was excellent with sewage water irrigated fields. He noted that sewage has been applied by trickle irrigation near Elat. Enteroviruses survived in the wet area around the trickle emitters for about 2 weeks. Crops were not contaminated when the wetted soil was covered with plastic. He also presented some data, which he had shown earlier in the week, showing that the disease rate in villages near sewage farms in Israel was higher than in other areas.

Noonan commented that fecal coliforms moved about 900 m in the groundwater from an application site in Canterbury, New Zealand. The soils used were very coarse sands and gravels. The amount of nitrogen in the groundwater was already high and changes after sewage application could not be detected.

Pound, in response to a question from the floor, noted that boron could present a problem in irrigating some crops if its concentration in sewage is more than 1 ppm.

Lance, in summarizing the discussion of various land treatment systems, suggested that the local situation should determine the kind of land treatment used. Low-rate systems require large areas of land devoted to crops which can be utilized without a disease hazard. Rapid infiltration systems require highly permeable soils. Water from high-rate systems can be reused for irrigation, recreational lakes, or industry. Overland flow systems can be used on impermeable soils where no other land treatment system is feasible. In some cases it may be desirable to use a combination of different systems. For example, water could be treated in a high-rate system and then used for unrestricted irrigation.

D. Other Observations and Comments

The discussion from the floor and informal discussions indicate that some people still do not understand what really happens when sewage is added to soil. Many people assume that the continued application of sewage will result in an accumulation of organic matter, fecal bacteria, or salts which will clog the soil and curtail the life of the system. This is a question which is asked at almost every meeting on land treatment. We must continue to try to communicate the fact that a properly operated system with resting periods for oxidation of organic matter, nitrification, etc. can be used indefinitely. Hopefully, reports on systems used for many years will help to solve this problem.

The movement of viruses through the soil to groundwater is a matter of concern to many. Reports of movement through some soils and lack of movement in others has created confusion. More work is needed on virus adsorption by various different soils to clear up this confusion. At the present time, the reports of movement through several feet of soil have been for coarse soils and gravels. Adsorption was high for the loamy sand (2 to 3 percent clay) used in our experiments at the Water Conservation Laboratory. Probably virus adsorption is even higher for mineral soils which are finer in texture than a loamy sand. Exactly how many feet of travel are needed under various management practices needs to be established. Also, I have the impression that reports showing virus movement have led some people to think that viruses move through most soils. Actually, the experimental data show that viruses probably do not move through soils except in special cases like very coarse sands, possibly some organic soils, and others which need to be identified.

Several people in private discussions voiced the fear that the epidemiological report by Shuval may be misinterpreted. This report has been approved for publication in *Science* and may have a "headline" effect. Some important points were not mentioned in the oral reports by Shuval and may not be included in the published paper. First, the water used for irrigation was almost the equivalent of raw sewage. It had received 5 to 6 days detention time in oxidation ponds. Also, the level of enteric disease organisms in sewage in Israel is often orders of magnitude higher than the maximum levels reported in the United States. This is due to the fact that less water is used in collecting sewage in Israel and thus the sewage is more concentrated. Also, Shuval stated that the incidence of enteric diseases in the areas served by the sewage treatment system is higher than in the United States. It is unlikely that raw sewage would be used for spray irrigation in the United States. Even if raw sewage was used, the enteric pathogen level in the water probably would be considerably lower than in the water used in Israel. Therefore, it is doubtful that the results from this report could be applied to the United States. This does not mean that the data are not valid but simply that experimental conditions were much different than in the United States. The results do apply to Israel and probably to many other countries.

In private conversation McPherson indicated that a check of absentee records for the Werribee farm employees during 1975 showed a lower rate of absenteeism for farm employees than for other employees of the Melbourne and Metropolitan Board of Works. This does not carry the weight of an epidemiological study, but this data, along with the long experience of Werribee, indicates that this system has not created a health problem for its employees or nearby residents.

IV. CRITIQUE OF SESSION

Many people attending the meetings were interested in answers to practical problems which they could not obtain from formal papers. I think that at least some of these questions were answered by the Workshop. The presentations were well organized and appeared to be well received by the audience. Much information was presented on rapid infiltration systems and this seems appropriate since these systems are not always discussed in land treatment sessions. Since land treatment technology can be applied in both developed and developing nations, such workshops are a valuable part of international meetings.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The results reported at the Workshop indicate that land treatment may be used in many cases to prevent water pollution. Of course, it can't be used in every situation. More information needs to be developed to assist in determining the best system to use. This would include instructions on how to use the soils data available from the Soil Conservation Service to determine what kind of land treatment system, if any, could be used for a particular location. Also, it is obvious that more data on economic comparisons of different sewage treatment systems are needed.

This meeting and other similar ones show that more work needs to be done on the management of land treatment systems. Many systems have been monitored to determine the removal of pathogens and nutrients, but in most cases little work has been done on ways to improve land treatment systems. Field and laboratory work in conjunction with the Flushing Meadows project has shown that the treatment can be drastically changed by different management practices and that there is great potential for further development of land treatment systems. Also, more work is needed on the way different soils respond to applications of sewage. For example, little is known about movement of viruses through many of the soils available for land treatment. The effect of different soil characteristics on various treatment aspects needs more attention. This would facilitate the transfer of information between locations. Also, the effect of climate on various treatment systems needs more attention.

In summary, this Workshop shows that many land treatment systems have been successful for long periods of time. This shows that further application of our knowledge of the physical, chemical, and biological processes operating in soils and further experimentation should greatly increase the usefulness of land treatment as a method to prevent water pollution.

I. SESSION

A. Theme of Session: Removal of Organics

B. Paper Presented: 59. Removal of Organics in Sewage and
Secondary Effluent by Reverse Osmosis.
E. S. K. Chian, S. S. Cheng, F. B. DeWalle
(USA)

II. REVIEWER

A. Name: E. Robert Baumann

B. Position and Affiliation: Professor of Civil Engineering
Iowa State University
Ames, Iowa 50011

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 59

Reverse osmosis is a versatile separation-purification process for separating pollutants from industrial and advanced water and wastewater plant effluents. Most research emphasis has been on removal of inorganics, but recently Chian at Illinois began a study of RO characteristics for removal of organics. The understanding of the basic mechanics involved in separation of organics by such membranes would improve process design.

Separation of organics by RO membranes depends on the molecular sieve characteristics of the membrane and on the characteristics of the organic molecule. The membrane sieve characteristics affect the degree to which organic molecules are removed and the rate at which purified water (flux) is produced.

The removal of organics from wastewaters is dependent on the operation of previous biological treatment units because this determines the molecular weight distribution and nature of the organics present. However, little has been known about 1) the organic compounds in activated sludge (AS) effluents, and 2) the relation between operating parameters of AS units and the organics in the treated wastewaters. The purpose of this study was to operate AS units at two loadings (F/M ratios of 0.33 and 0.69) and remove organics from the AS effluents using RO so that organics removal could be correlated with AS unit operation. Specifically, the study classified the organics by particle size and molecular weight (by gel permeation) and by identification of the organic chemical composition (gc-mass spec.).

Two AS laboratory units were operated on domestic sewage at F/M loadings of 0.33 and 0.69 g BOD/g MLVSS-day^{-1} for two to three months to assure equilibrium conditions to develop. A 3-day batch composite raw and treated effluent was collected and subjected to tertiary treatment by RO. The wastewaters were first centrifuged (12,500 rpm) and filtered through 0.45 μm membranes for removal of suspended solids and microorganisms. The filtrate was concentrated by ultrafiltration (UF) using a membrane having a MW cut-off of 18,000. The UF permeate was subjected to RO treatment using a membrane having a MW cut-off of about 150. UF processes operated at 28 psi; RO processes operated at 750 psi at 25°C.

All wastewater samples were examined for MW distribution of the organics to estimation of their apparent molecular weight (AMW). The RO permeate analysis was conducted using gas chromatography for compound separation and were identified using a mass spectrometer.

The AS units provided treatment results as follows:

	F/M = 0.33	F/M = 0.69
Raw BOD_5, mg/ℓ	178	178
Effluent BOD_5, mg/ℓ	4.1	6.3
Raw TOC, mg/ℓ	12.9	72.9
Effluent TOC, mg/ℓ	14.2 (11.1 soluble)	24.1 (18.0 soluble)

The BOD removal was nearly equal in both units, but TOC removal varied significantly with the lower loaded unit providing best performance.

The results of MW distribution in the AS, UF and RO effluents indicated that the unit efficiency is highest in the removal of the lowest MW fraction. The efficiency of removal of a given MW distribution decreases as the MW of the organics in each fraction increases. In all cases, the percentage removal of organics is highest for wastewaters treated in the low loading (F/M = 0.33) unit. The changes in the percentage distribution of MW is not the result just of a change in the size of the organic material, but involves a complex change in organic species as a result of biological activities associated with the AS units.

Separation of the organics in both sewage and effluent from both AS units by gel permeation indicated that there exist two apparent TOC peaks in the UF retentate and only one in the RO retentate. The apparent molecular weight (AMW) distribution of each of the UF and RO retentates was computed. The TOC recovery after the gel permeation experiments was determined. The results shown in Table 3 (from original paper) indicate that the AMW in the RO retentate appears to increase as the AS cell residence time increases. The MW also increases with decreasing F/M ratio in the UF retentate.

The most interesting finding in the study is the fact that the F/M ratio operating parameters are closely related to the quality of the effluent which can be produced by RO.

Table 3*

Apparent Molecular Weight Distribution (Dextran) of Soluble Organics in Representative Samples as Percentage of Initial TOC of Samples**

Sample	UF Retentate			RO Retentate	RO Permeate
Sewage		28.8%		41.3%	29.9%
	12.4%	3.1%	13.3%		
MW	>50 K	2-5 K	<2 K	>150	<150
		(102)***		(97.7)	(99.4)
Effluent (F/M = 0.69)		42.2%		40.6%	17.2%
	18.1%		24.1%		
MW	>50 K		<2 K	200	<150
		(99.5)		(99.9)	
Effluent (F/M = 0.33)		52.2%		41.5%	6.3%
	28.3%	3.9%	19%		
MW	>50 K	5-50 K	2-5 K	250	<150
		(102)		(100)	

*Table from original paper

**See Table 2 (original paper) for initial TOC of these soluble fractions

***Numbers in parentheses indicate the average percentage of TOC recovered from the Sephadex G-75 and G-25 columns

The following conclusions were drawn:

1. The operational parameter, i.e., the F/M ratio in the operation of an AS unit, is very important in affecting the organic content in an RO effluent. The highest RO permeate quality is obtained with the lowest F/M ratio.

2. The RO units should only be operated on AS effluents operated at low loadings using filtered wastewater to eliminate membrane fouling.

3. Gross MW size fractionation studies of the organic matter must be complemented with gel permeation studies to relate MW distribution of the organic matter in secondary effluents to its removal by RO.

4. The quality of the RO permeate treating wastewater from low loading AS units was comparable to distilled water.

B. Prepared Discussion

The formal discusser, M. A. Baud of France, did not attend the conference. The name of the formal discusser is not known to the reviewer.

This work represents a turning point in the study of RO and, in particular, the removal of organics by RO. It is not a simple application of RO to wastewater upgrading with mundane, standardized process evaluations. Three new, unique, and significant techniques were carried out simultaneously in the same study:

1. Use of new techniques to the field for determination of the relative distribution of soluble organics in wastewaters.

2. Application of these techniques to provide data for a study of AS process efficiency in providing effluents suitable for subsequent RO treatment.

3. Determination of the possible effect of F/M ratio in operation of AS units for improving the efficiency of UF and RO units in organics removal.

The paper is very clear and precise in describing apparatus and techniques so that others should be able to reproduce the authors' results and use the techniques in their own work. The authors demonstrated that studies in all three areas could be conducted simultaneously to provide a significant improvement in study results.

Two areas of potential study deserve attention:

1. All biological breakdown processes break down the MW of the soluble organics and therefore increase the biodegradability of the organics.

2. Physical-chemical processes used for tertiary treatment (activated carbon, macroreticular resins, RO) all have better output efficiency with large MW organics.

So, how can we keep the large MW organics suitable for removal using physical-chemical processes? The discusser had several questions:

1. Although the percentage recovery reached in the AMW studies reached 100 percent, can we wonder about the loss of volatile materials?

2. Would not an additional extraction be helpful to get an additional MW range?

3. Should not the methods be expanded to evaluate what goes on using other processes, such as activated carbon adsorption?

C. Floor Discussions

Wechsler (Australia). Several questions were raised:

1. If it is important to remove SS prior to RO units, is the problem with bacterial slimes?

2. Why did the authors use hollow fibers if the maintenance of flux is a problem with SS?

3. Can you identify the RO peak?

Peter Gibbs (Australia). The University of New South Wales has operated an extended aeration plant followed by UF (12 ft^2) for solids/fluids separation. Using a synthetic sewage with a BOD of 200-300 mg/ℓ and a F/M ratio of 0.12 day^{-1}, the unit provided 80-85 percent BOD removal and the BOD of the ultrafiltrate was about 35 mg/ℓ. The pilot plant was operated at 4.5 ℓ/hr to a 45 psi drop on the UF unit. This work has been published. (?) What was the dependable flux on the authors' RO unit?

T. Waldmeyer (UK), the recorder. I had hoped for more discussion of low MW organics. In 1970-71, the UK Stevenage Lab studied this problem. Their main effort was to determine methods and techniques for identification of organics. Using high pressure liquid chromatography, they identified almost 90 percent of sewage organics - mostly sugars, low MW volatile acids, detergent residues, ureas, etc. Stevenage has operated a pilot RO unit for 12 months (still going) by use of a warm detergent cleaning solution. However, the original promise of RO has not been fulfilled. The only UK application of significance is in the dairy industry for whey recovery.

E. A. Pearson (US). It becomes very clear that attention must be directed to the species effectiveness of RO processes. The real interest is in the removal of specific organics, not BOD or TOC. California has pending regulations which would require all recharged wastewater to be treated with all tertiary processes, including RO.

What is the real cost of a 10 MGD RO process? What is the membrane cost as a percentage of total cost?

Reply - We have completed studies to show the biological breakdown of organics. Long time AS with SRT of 20 days will reduce organic MW to the level where RO is of no value. The suspended solids removal prior to RO should include alum mix, clarification, granular media filtration, and pH adjustment to 8 to 9. UF is good for removal of suspended solids and UF and RO in series make a good team for that purpose. We used hollow fiber which does require more suspended solids removal by pretreatment. With tubular units, pretreatment costs are reduced. It is really only a problem of economics which determines which you use. The results of organics removal are not affected.

We are using the paper's techniques to look at trace organics in drinking water. Illinois has six postdoctoral staff members at work on a $500,000 per year study. The cost of a 130 MGD plant at Yuma, Arizona, was $60,000,000 for the AS system and $60,000,000 more for RO treatment. Total operating cost is 50-60¢/1000 gal. We have studied rejection of 500 compounds by RO. Small plant construction costs will be about $1/gal/day and operating costs will be about $1.50/1000 gal.

IV. CRITIQUE OF SESSION

This paper was, by general consensus, one of the two or three best papers presented at the conference. The techniques used to classify MW ranges and to evaluate RO performance are not well known or frequently used in the field. The results confirm the importance of making more detailed process evaluations prior to mass movement to new processes.

The authors are to be commended for a particularly interesting, effective presentation.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The techniques used in this paper are important in evaluating what effects prior biological treatment will have on several tertiary treatment processes such as use of activated carbon or XAD resins for organics removal. Studies should be conducted to evaluate their performance in studies similar to those reported in this paper.

Unfortunately, few universities or treatment plants will have the requisite trained chemists and the expensive equipment necessary for conducting studies of this type. It will be deplorable if everyone rushes in to cash in on the technique. Only three or four groups in the U.S. should probably be supported in this area of work; one should be in EPA's own laboratories.

The ability to identify AMW ranges is not as important as the ability to identify specific compounds. Grants should be made to provide general support of a long term nature to three or four groups for work in this field.

The study reveals very effectively the conclusion that for "optimization" of total wastewater control we need to develop models for prediction of what happens to organic compounds in waste streams, not just BOD and/or TOC.

I. SESSION

A. Theme of Session: Tertiary Wastewater Treatment

B. Paper Presented: 62. Series Intermittent Sand Filtration to
Upgrade Wastewater Lagoon Effluent.
D. W. Hill, J. H. Reynolds, S. E. Harris,
D. S. Filip, E. J. Middlebrooks (USA)

II. REVIEWER

A. Name: E. Robert Baumann

B. Position and Affiliation: Professor of Civil Engineering
Iowa State University
Ames, Iowa 50010

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 62

The purpose of the study reported was to develop design criteria for intermittent sand filters used to polish lagoon effluents. Most lagoons now are required to provide an effluent BOD_5 below 30 mg/ℓ; Utah now requires that lagoon effluent BOD_5 be less than 5 mg/ℓ. Previous studies at Utah State had indicated that single-stage intermittent sand filters provided a simple, economical, reliable method of wastewater treatment but the filters used resulted in very short filter runs (14-42 days) and operating problems. This study, therefore, was directed at evaluation of series operation of intermittent filters using larger media in the first filter with the specific purpose of increasing the length of filter run for "optimization" of the process.

To evaluate the effectiveness of series intermittent sand filtration of lagoon effluents, nine 16-sq ft surface area filters in three sets of three filters in series were operated at different loading rates. The three sets of series filters all had 0.762 m of sand and 30.48 cm of gravel on the bottom for a drain. The sand sizes were:

1st filter in set - 0.72 mm
2nd filter in set - 0.40 mm
3rd filter in set - 0.17 mm

The hydraulic loading rates used were 0.5, 1.0, and 1.5 mgad (4,700; 9,350; and 14,000 m^3/hectare-day). (Uniformity coefficient of sand was not recorded. The filter media was uniformly distributed in the filter.) Samples of filter influent (lagoon effluent) and filter effluent from each filter in the series were collected weekly and analyzed for BOD, SS, VSS, pH, temperature and dissolved oxygen from the period July 23 to December 2, 1974. The system was shut down without termination of any filter run after 130 days due to freeze-up of the waste lines from the Logan Municipal Sewage Lagoon to the study filters.

Figures and tables are provided in the paper to tabulate the filter operating results. Studies of algae present in the samples indicated that a small, coccoid blue-green algae (*Aphanocapsa sp.*) was the predominant algae. Total algal populations in the lagoon effluent varied from 5,000 to 275,000 cells per mℓ.

All filters were still in operation after 130 days; thus, none were run to failure. The dosing cycle (remember, these are intermittent sand filters) was not described, but the "applied influent load passed completely through all three filters" in a set within four hours.

Lagoon effluent BOD varied between 4.1 and 23.4 mg/ℓ. The 1.5 mgad loaded filter produced an effluent BOD between 0.6 and 4.1 mg/ℓ. Filter efficiency increased with run length due to the buildup of a surface layer of solids on "each" filter. Mean BOD levels in mg/ℓ on the highest loaded filter set were:

Lagoon effluent = 10.5
1st filter effluent = 8.2
2nd filter effluent = 5.8
3rd filter effluent = 2.3

Lagoon effluent suspended solids levels varied between 12.5 and 69.4 mg/ℓ and averaged 31.7 mg/ℓ. The average results on the filters with highest mgad loading rates were:

Lagoon effluent SS, mg/ℓ = 31.7
1st filter effluent SS, mg/ℓ = 16.1 (0.72 mm sand)
2nd filter effluent SS, mg/ℓ = 14.1 (0.40 mm sand)
3rd filter effluent SS, mg/ℓ = 6.4 (0.17 mm sand)

Again, suspended solids removal improved as the filter run progressed due to buildup of solids on the filter surface.

Mean volatile solids levels, in mg/ℓ, from the highest loaded filter set were:

Lagoon effluent = 21.3
1st filter effluent = 9.8
2nd filter effluent = 7.0
3rd filter effluent = 3.3

The tests conducted using a lightly loaded lagoon effluent indicated that series intermittent sand filters (3) could produce an effluent BOD less than 3 mg/ℓ, effluent SS less than 9 mg/ℓ, and effluent VSS less than 4 mg/ℓ at a loading rate of 1.5 mgad with a run longer than 130 days.

The authors recommended design criteria as follows:

Hydraulic rate - 1.6 mgad (14,000 m^3/hectare-day)
(Flow rate divided by area of a single filter)

Filter sand size, mm - 1st filter - 0.65-0.70 (special processing)
- 2nd filter - 0.35-0.45 (special processing)
- 3rd filter - 0.15-0.25 (pit run sand)

Uniformity coefficient - 2 to 10

Filter bed - 0.914 m of sand (minimum of 0.61 m), 0.304 m of 1.27-2.54 cm gravel; drains embedded in the gravel

Sand cleaning - hydraulic backwash after removal from the bed

Embankment - same as for lagoon system

Influent-effluent drain system - size to dose filters in less than 6 hr

Operation mode - hold lagoon effluents during peak algal loads; load filters at night

Total operating costs of series intermittent lagoons were estimated to be $67-70 per million gallons of filtrate.

B. Prepared Discussion

The appointed discusser of this paper (G. Shelef, Israel) commented and raised the following questions:

1. He could argue the validity of the effluent standards, but if the treatment cost is only 6-7¢/1000 gal, he concluded that lagoons followed by series intermittent sand filters was a sound-logical design approach.

2. The quality of the Logan, Utah, lagoon effluent was already superior to that required in Israel which are operated at far higher loading rates. Since the algae themselves have a low BOD, they should not be limited by an SS limits imposed. Do you agree?

3. In Utah, the most prolific algal species encountered is also the one that is most easily filtered out. What happens when a difficult filtering algal species is encountered, as they are yearly in Israel?

4. Why were no fecal coliform determinations made in the study?

5. The filtration system itself for the purpose outlined can take many forms. In Israel, sand dunes have been successfully used.

C. Floor Discussions

Dahlem (West Germany). In Table 1 in the paper, the zooplankton dimension is not given. What zooplankton prevail?

Ben-Harim (Israel). You reported filtration rates up to 1.5 mgad. Did you use higher rates?

Participant (West Australia). Intermittent sand filters have been used for over 100 years. Aren't you confusing the issue by reinventing them? Why not put all your different sized media in layers in one filter?

Baumann (USA). The cleaning of series intermittent sand filters is based on scraping off the surface film that forms. Yet, your data demonstrate clearly that solids do penetrate the media and that there must be depth removal of such solids. Have you given any thought to the fact that in 5 or 10 years the filter may have to be completely rebuilt due to the progressive nature of such clogging?

Reply - Intermittent sand filters are not new and the authors have never claimed them to be. We are merely applying an old process to a new problem and we are trying to define how this can be done successfully.

In the study, a 5-cell series lagoon was used to supply wastewater by drawing effluent from the second lagoon. Therefore, our lagoon site was a poor choice since the wastewater quality is so good without filter treatment. We have encountered small algal species and had them removed by our filters. I know, however, of an Oregon plant where very small algal cells are not removed in a filter like ours. Coliform removal was uniformly high, with effluent counts below 100/100 ml. We have heard that operation of series intermittent filters for two days with two days of rest would eliminate the need for cleaning. We tried it; the filters require cleaning.

Layering of the filter media in one filter unit would provide an interface where surface (interface) removal would occur at a place we cannot get at to remove it. In our experience, most of the solids removal is at the surface and we - at least in our study periods - have not had problems with depth removals of the suspended solids. The zooplankton were principally daphia. We have tried loading rates to 16 mgad, but run lengths are seriously reduced at rates over 3 mgad; the effluent quality is not degraded significantly.

Waldmeyer (UK). British experience indicates that series intermittent sand filters require that a very high quality of effluent be applied to them before they will perform satisfactorily over the long term.

IV. CRITIQUE OF SESSION

This paper does outline the application of an old process for solving a current problem, the upgrading of lagoon effluents. The study conducted did not generate any real enthusiasm on the part of the audience, particularly with those who have familiarity with lagoons or with filters. The results of the study as reported suffer severely from the following limitations:

1. The lagoon selected for use in the study is definitely not representative of a normally loaded lagoon.

2. The study was made with only three media sizes and at only three wastewater application rates. At no stretch of the imagination could we conclude that sand size, sand depth, and wastewater application rates are anywhere near at optimum criteria.

3. The filter runs were not conducted through even one cycle, since the filters never needed cleaning. How can we be sure that continued cleaning of only the surface would leave the solids removed with depth still in place and ultimately in 1-2-3-4 years cause complete failure of the system? No provisions are made for depth cleaning of the media.

4. Thus, the extrapolation of results from this study to establish general design requirements would be tenuous at best.

5. It would appear desirable that plant-scale installations be made on normally and overloaded lagoons to observe the operating characteristics of series-intermediate filters over a period of years and the results recorded and reported. Installations should be made on both storage lagoons (as at Iowa where all wastewater is stored from about December 1 to April 1) and flow through lagoons. This reviewer would expect real problems to develop! Conversations with Australian, British, and Israeli conference representatives indicated that they had the same fears.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Series intermittent sand filters used for polishing of lagoon effluents represents the application of an old process for solution of a new problem. The filters obviously can work. The filters obviously will ultimately clog and need complete rebuilding. We do not have good data to optimize design. We do not have "real plant" operating experience to indicate confirmation of the pilot plant results reported in the paper.

The technique, however, has real merit in that it is a low energy, low labor, cost effective (barring rebuilding needs) method of removing algal cells and residual BOD from lagoon effluents.

This reviewer presently is concerned about discharge of algal cells from lagoons not because of the BOD discharged to the river but because the algal cells constitute a continuous source of seed into waters containing loads of nitrates and phosphates (in Iowa, anyhow) from agricultural runoff. Our only major ammonia fishkill occurred with a spring lagoon emptying with plankton counts of over 1,000,000 cells/mℓ. These cells hit the Racoon River where plankton counts increased 2 or 3 times in the 15 miles below the discharge point sending the pH of the river from 7.5 to at least 9.3-9.4. The ammonia level in the river from the lagoon was in the range of 10-15 mg/ℓ. Fish kill was inevitable. We must give consideration to removal of such algal cells from lagoon discharges. We need better information on the feasibility of long-term service of series, intermittent sand filters for this purpose.

I. SESSION

A. Theme of Session: Ion Exchange

B. Papers Presented: 65. Ion Exchange in a Moving Bed of Magnetized Resin.
B. A. Bolto, D. R. Dixon, A. J. Priestley,
E. A. Swinton (Australia)

68. Recovery of Zinc using Chelating Resin.
H. Uejima, M. Hirai, T. Ishibashi (Japan)

71. Water Demineralization by a Thermally Regenerable Ion Exchange.
B. A. Bolto, N. H. Pilkington, P. M. Sharples,
G. K. Stephens, K. O. Wade, D. E. Weiss
(Australia)

II. REVIEWER

A. Name: Alan H. Molof

B. Position and Affiliation: Associate Professor of Civil Engineering
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III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 65

The paper given by Dr. Priestly covered three main areas. These were:

1. Structure of a typical magnetic resin
2. Dealkalization process using weak acid magnetic resin
3. Entrained flow pipe line as the adsorber (ion exchange) vessel

The structure of a typical magnetic resin consists of an inert polymeric core of cross-linked polyvinyl alcohol in which is distributed fine particles of magnetic gamma iron oxide. Around the core is grafted the shell of the resin material. In this case the weak acid resin is polyacrylic acid.

The unmagnetized form has a settled slurry voidage of 0.32. Upon magnetization the magnetized resins form into ringlets of higher void volume. Settling produces a slurry with a voidage of about 0.4 which allows easy transfer by pumping with low resin attrition and low pressure drop.

A dramatic increase in settling rate occurs upon magnetization. The settling rate of the fine size magnetic particle (60-70 μm) is equal or greater than much larger size conventional resins. This property allows separation in simple settling tanks and wet magnetic separators and also allows use in fluidized beds at a relatively high superficial velocity.

The small particle size results in rapid ion exchange. With weak acid resin there is an increase of about 6 to 7x over conventional Amberlite IRC-84.

One of the first uses of the magnetic resin was in the dealkalization of a hard alkaline bore water using a weak acid resin form. In this reaction there is a simultaneous removal of hardness and alkalinity in one reaction. The process flow diagram consisted of a vigorous fluidized bed for the exchange vessel and an incipient fluidized bed for the regeneration vessel. For regeneration the flow was counter current with the resin down and the acid up. The exchange column ID was 30 cm and the regeneration column 13 cm with a flow of 30 ℓ/day. An eductor was used for physical transport with little physical attrition.

There was essentially complete dealkalization with concurrent calcium removal and a small amount of sodium removed. Compared to results with more complicated continuous ion exchange processes, the magnetic resin process obtained the same degree of dealkalization but with simpler equipment, less resin, higher concentration in effluent and lower flow rate.

Application of the magnetic resin process to wastewater treatment would require equipment to handle highly turbid waters with small particle resins. Fluidized bed was not found satisfactory. The proposed alternate was an entrained pipeline in which the resin is carried in turbulent flow.

The feed and resin flow are concurrent to a settling tank where the settled resin is transferred to a pipeline regeneration with acid. The regenerated resin goes to a water separator and wash such as a vacuum filter. The washed regenerated resin is returned to the exchange section. The equipment is simple except for the vacuum filter. However, the high filter rates would result in small size filters.

A cost comparison shows the entrained flow pipeline process to require the least volume for exchange and the smallest resin inventory for the several alternates considered. The capital cost was estimated to be half of the equivalent fluidized bed process.

A pilot plant was used at a physical-chemical plant handling primary settled wastewater. The feed was from the base of the ammonia stripping tower following lime coagulation. The pipeline was 60 m long with a 2.54 cm ID plastic pipe. The velocity at 0.7-0.8 m/sec was sufficient to fully entrain the resin.

The results showed rapid dealkalization with a contact time of 70-80 sec to lower the alkalinity to low levels. The results were more rapid than that predicted from a previous design study. It was thought this was due to the turbulence pulling the flocs apart exposing more exchange area. The entrained flow pipeline in a large scale application would require a 75 cm ID pipe with a velocity of 1.2 m/sec for a 45 Mℓ/day (10 mgd) flow. Advantages included simplicity, no high pressure, no blocking of streams, less resin, small plant and no preclarification needed.

A.2 Paper No. 68

This is a report on the use of a chelating resin, Unitika UR-10, to remove zinc from an industrial waste and concentrate it sufficiently so that the zinc can be reused in the polyvinyl alcohol fiber process. There is a high calcium and sodium content compared to zinc requiring a high selectivity resin such as UR-10. After the metal is removed, the organic material in the waste (formalin) at 500 mg/ℓ is treated by activated sludge. The resin selectivity coefficient for ZN was 12 and for Ca was 1.

The zinc must be a concentration of at least 96 percent based on a zinc-calcium mixture. The normal zinc recovery is as high as 88 percent. Therefore, a major process development was required to raise the zinc removal in the presence of calcium. The wastewater had a pH 1-2; zinc, 21.5 mg/ℓ, calcium, 76 mg/ℓ; sodium, 600 mg/ℓ; iron, 0.7 mg/ℓ; copper, 0.2 mg/ℓ; and formalin, 580 mg/ℓ.

The first scale was a laboratory level using a 1.5 cm resin column. The operation cycle was: sodium salt form, adsorption of Zn, elution with acid, and regeneration with NaOH. The total adsorption capacity of the resin was 0.6 mol/ℓ-RNa. The best pH was 5-6.

Calcium having a low selective adsorption was affected by sodium significantly more than was Zn. This fact was used as the basis of raising the purity of the recovered Zn.

One test passing the wastewater through the resin followed by acid elution yielded a zinc/calcium weight ratio of 80:20. If a zinc sulfate solution (250 mg/ℓ Zn) was passed through the resin before the acid elution, purity of the recovered Zn in the acid elution reached as high as 97 percent. The acid was H_2SO_4.

The first process scale-up was to the middle scale with a 70 cm diameter resin column 153 cm high. The process had neutralization followed by a filter and the resin column. To avoid problems resulting from the resin reducing its volume by 25 percent when the metal was adsorbed, a limit of 0.5 mg/ℓ suspended solids at a space velocity of 25 was required. The suspended solids were mainly from hydroxide and $CaSO_4$ at 5-20 mg/ℓ from the neutralization. A limit of 2 mg/ℓ Zn in the effluent was monitored. This was done by a chemical indication test developed by the authors for this particular waste.

The second scale-up was in the full scale plant with a wastewater flow of 100-120 m^3/hr, 15-20 times as much as the middle scale. The Zn was almost completely recovered and the Zn content of the eluate was high enough for reuse. The iron and copper were reduced to nondetectable levels. The activated sludge plant yielded a 95 percent COD removal.

A.3 Paper No. 71

The process described is for removing small quantities of salt from large volumes of water. The feed water is mildly brackish up to 3000 mg/ℓ total dissolved solids (TDS). The main advantage of the process is the ability to regenerate the resin with hot water, the cheapest regenerate. The resin and process are called Sirotherm. A commercial plant is in operation and the resins are being distributed around the world. Testing started in 1973.

The resin is a mixture of weak acid and weak base groups to adsorb cations and anions respectively. The hydrogen and hydroxide for regeneration is supplied by the hot water. The equipment is conventional, fixed or moving bed, co- or counter-current regeneration.

The first full scale plant removes 80 percent salinity with a feed of 400-600 mg/ℓ in Adelaide, South Australia. The flow is 600 m^3/day and the process acts as a pretreatment for boiler feed water.

The flow sheet consists of: alum coagulation and filtration, ion exchange organic trap column, strong acid resin softening regeneration with NaCl, H_2SO_4 to pH 3.8, vacuum degasser tower, pH adjustment by caustic to neutral, and Sirotherm column. The acid destroys the alkalinity and the liberated CO_2 and dissolved oxygen are removed in the degassing tower. Neutral pH is a requirement for the feed. Removal of dissolved oxygen is also required since the resins will be slowly oxidized at the elevated temperature of regeneration.

Another major application of the process is in the renovation of wastewater for reuse. The typical salt content is 1000-2000 mg/ℓ TDS.

Organic fouling is a major problem since it reduces capacity at a rate too rapid for practical purposes. The capacity loss was not permanent since it was possible to renew the resin by caustic and brine chemical regeneration. By using a pretreatment of a conventional organic trap resin to remove organics not removed by activated carbon, the fouling organics were captured (MW 1000-10,000) and the Sirotherm capacity was not reduced.

A 20 m^3/day pilot plant similar to that used in Adelaide was used in Japan where reuse is a very high priority. The pilot plant followed an activated sludge plant with tertiary treatment including carbon. There were dramatic changes in salt feed levels over the 1000 cycles of operation with 3-6 mg/ℓ COD in the Sirotherm feed.

The advantages of the process include cost, i.e., cheapest energy for regeneration (low grade heat 80-90°C), minimum chemical pollution, offers large interfacial area and has low capital and operating costs.

B. Prepared Discussion

B.1 According to the discusser (A. D. Carr, South Africa), they are doing work at Capetown on treatment of secondary effluent to produce potable water. Part of the treatment is a vertical multi-stage continuous ion exchange column. At the start each stage is half full of resin. In the upflow cycle when loading the column the resin in each stage is fluidized for about 4 min. Then the resin is settled and transferred to the stage below.

After several cycles, the resin will deplete at the bottom stage and overfill at the top stage. The problem comes from the density ratio of the resin/solution which is 1.06 at the top and 1.2 at the bottom. If a heavy resin such as the magnetic resin could be used, the resin problem could be solved. The first question was - is it possible to use the magnetic resin in equipment such as the vertical multi-stage column with a short period for settling and transfer of resin of about a half minute? If not, is there any basic disadvantage to making a larger resin?

In multi-stage operation, the kinetic advantage of small size resins is often lost due to time constraints externally posed, i.e., the rate of transferring resin is usually critical and small size kinetic advantage would not be justifiable. Small resin size can be a disadvantage since they have found with dilute feed solutions that film diffusion, not pore diffusion, controls.

The second question asked for comment on the apparent interchangeable use of the terms "attrition" and "loss of capacity" by the authors, since the discusser has found attrition does not mean a marked change of loss of capacity.

The third question asked was in regeneration of the resin with strong acid and base, what is the possibility of permeation of the acid and base to attock the iron core and break up the resin?

B.2 R. K. Chalmers (UK) described the process as "elegant" and felt the process was "very clearly described," the investigation was "logical, direct and conclusive," and this was "an advancement in knowledge." Figure 2 in the paper needed explanation. It did not seem to mention Na nor is the link between that effect and elution of calcium ion with zinc sulfate very apparent.

It was not clear what is done with the $ZnSO_4$ used to elute the adsorbed calcium from the resin. Did it come off within purity restriction for calcium for reuse? If not, what happens to it and how much zinc is lost in the treatment?

It was surprising to find worthwhile the recovery of 50 kg/day of zinc for reuse water purposes while no mention was made by the authors of recovery of more expensive metals such as cadmium, copper and nickel. He asked the authors to comment.

The discusser posed several questions:

1. Was there any danger of tracking liquid down the side of the 1.5 cm diameter column used in the initial studies?

2. What determined a diameter of 70 cm in the middle scale plant? The lab was 1.5 cm, the middle scale 70 cm, and the full scale 15-20 times larger. The discusser's experience was that a final scale-up of 100 times was justifiable.

3. What was the alkali consumption in raising the pH to 5-6? Was there any precipitation in the effluent? Why was a settling tank introduced in the full scale plant before the filter?

4. In the precipitation of $CaSO_4$ in pretreatment, is a supersaturated solution of $CaSO_4 \cdot 2H_2O$ left? Has there been any problem with $CaSO_4$ precipitation in the ion exchange system? The discusser has experienced $CaSO_4$ resin column blockage.

5. Would the process be applicable to acid zinc solutions? Is there any instance of chelation resins being effective for metal cyanide complexes?

6. How often does the window in the color detection instrument need to be cleaned? Wouldn't it be better to use atomic adsorption or a limit test using dithiozone?

7. Is activated sludge applied to this waste alone or in combination with other wastes? 95 percent removal is "remarkably good." It would be desirable to know more details of activated sludge process.

8. The process holds promise as applicable to other fields.

B.3 F. G. deWilde (South Africa) stated the work was done with "utmost scientific care" and commented on the "clarity of writing." He was pleased with the cooperation of the industrial group with a scientific institution.

In an earlier paper in 1973, costs were presented of 6¢/m^3 for operation and resin replacement, and 8-10¢/m^3 for total cost including amortization and interest. What is the present cost?

The authors mentioned anionic detergents and organic acids (1000-10,000 MW) as fouling agents. Dr. deWilde asked for examples of the low molecular weight organic acids and bases that can be adsorbed and regenerated and examples of the high molecular weight that would not cause chain entanglement. He also asked for examples of industrial sites where the authors planned to use the process.

C. Floor Discussions

C.1 Dr. Van Vhet (South Africa). In the pipeline process with wastewater, it can be assumed that the suspended solids will be removed along with the resin in the settling tank and both will be passed to the regeneration section. What happens to the suspended solids buildup over a long period operation? If the rate step control is the external film, would this be a partial explanation for the increased rate seen in practice against the lab data?

Representative from Australia. The author mentioned cation resin in the paper. Is anion resin made and is it commercially available. The author reported resin capacity as 5 meq/g at about 50 percent iron or 10 meq/g for pure material. Is this usually high capacity used for dealkalization? Commercial resins will foul up from materials such as organics. Will the magnet resin foul up when used with wastewater?

D. E. Weiss (Australia). The purpose of the work described in the paper was to get a simple reliable technique for continuous operation in large scale operation since most ion exchange processes are not truly continuous. The design scale of operation is about 100 mgd plant size. Since large scale systems use processes as settling and percolation through sand, these processes are used as guides. The pipeline reactor has very good control of contact time, turbulent flow, plug flow and a settling device and is easy to scale to any size. The work done to date has been a single stage system only. Future work will be on multi-stage units.

Reply - The magnetic resin can be made in a larger size and therefore could be used in the multi-stage column. The increase in particle size will lose the advantage of kinetic rate but the advantage in separation and transfer are still retained and possibly enhanced. This is a problem in optimization.

The data indicate pore diffusion controls. However, independent of whether film or pore diffusion, the rate would increase with decreasing size but not as fast if it was film diffusion control.

There are two aspects of resin attrition - physical and chemical. The pilot plant was operated for 2500 hours with wastewater with little physical attrition. The changes, which were noticed, were due to a chemical effect. The cause was due to acid hydrolysis since in the initial operation there was no regeneration pH control and very low pH levels did occur. The experience indicates pH should not be lower than 2. If not, leaching and corrosion of iron can occur and damage the resin. There is also a low contact time in the regeneration of about one minute. Their operation at one minute detention at a pH of 3-4 indicated no problems.

If the settling tank is at the end of the pipeline or fluidized bed, a small amount of suspended solids will be captured and recycled to the regeneration column. It was not found to be a severe problem in the pilot plant work. If a magnetic separator is used instead of a settling tank, there will be little trapping of solids. Studies showed 99-100 percent of the influent turbidity out with the effluent.

A weak base magnetic resin has been made but it is still in the experimental stage. The weak acid resin has been used in a pilot plant but the resin is not yet commercially available.

The magnetic resin has a capacity of 4-5 meq/ℓ. Pure polyacrylic acid capacity would be 10 meq/ℓ. The resin capacity is about half. There were no adsorbed organics found on the resin and it appears that little adsorption occurs in the work reported.

C.2 One of the two floor questions (Dr. Sashe, Japan) concerned the effect of scale on overall selectivity. What type of factors did reduce to uneven velocity or uneven depressions in resin surface or did it come from size of operation? If not, could the authors identify any distinct cause-effect resin shape between selectivity of zinc and uneven adsorption that occurred. Possibly the adsorption may be the rate determining factor but the breakthrough characteristics may suggest a possible depth and velocity effect on changing selectivity.

The second floor question (Australia) concerned two aspects. The first aspect concerned the question on the molecular form of the resin and what was the functional group. The second aspect concerned the possible effect of volume change of the resin on the breakage of small lab columns (1.5 cm).

Reply - There was a misprint in Figure 2 in the original paper where Na concentration should replace Ve/Vh. In this figure Zn and Ca ions were studied separately. In full scale the total metal ion was only 0.3 kg/day lost outside. When calcium was eluted with $ZnSO_4$, about 2.5 kg/day of Zn will come out of the column. However, this solution of Zn^{++} will be returned to the settling tank. The system was studied for zinc because of a serious industrial waste problem involving zinc removal. This system has been used in Japan for Ni from metal plating.

The author agreed with the discusser's comments on scale-up. The plant scale-up was limited by capacity of filtration before chelating resin treatment. The $CaSO_4$ was not precipitated in this treatment but there was a possible $CaSO_4$ precipitation in elution process with $ZnSO_4$. The problem was solved by an operating change of dilution of $ZnSO_4$ before use.

The details of the activated sludge plant will be reported in the future. It is now being studied in the lab. The only feed is from the industrial waste treatment system reported here.

In responding to Dr. Sashe, the author stated that selectivity is a function of the concentration of metal ion, calcium in solution and the resin phase. This volume depends on activity of reaction phase, not contact time. It did not reach equilibrium state. Because reaction between resin and ion depends on adsorption, the apparent selectivity coefficient is very high with space velocity.

Responding to the discusser from Australia, the author commented that the functional group is amino acid. It contains OH group in polymer matrix and has hydrophylic properties. The base co-polymer is styrene-divinyl benzene. Their UR-10 resin is very effective.

C.3 Cosgrove (World Bank). In developing countries many water supplies are greater than the WHO level of 1500 mg/ℓ TDS. The present salt removal process requires technology to operate. Would your system be simpler to operate?

Stevenson. Could your process be used to remove nitrate in simple small units?

Reply - The costs now are about 7¢/m^3 for a 10 mgd plant and 16¢/m^3 for a 0.1 mgd plant. The cost will also be a function of the salt removed and the cost for heat. An advantage is that the heat is low grade and can often come from industrial waste heat sources. In addition solar heat could be applied.

Work on organic fouling has been done with sulfited alcohols up to C_8-C_9 which was no problem in regeneration. From C_9-C_{16}, there were some problems with branched chains but could still regenerate with caustic brine. Proteins with molecular weight >15,000 were excluded. Most common sources of fouling are the carboxylic acids, i.e., humic and fulvic acids. Analysis of material stripped from organic fouled resin showed carboxylic acids with MW range of 1000-10,000. These could be removed with difficulty with caustic brine. These organics can be removed with organic resin pretreatment to avoid resin fouling. They are working on building a charge on the surface interface so larger molecular weight compounds would not penetrate the Sirotherm resin.

The pilot plant in Japan has been moved to the Central Chemical Research Lab to recycle laboratory wastewater. O_3 is being used which might change the organic fouling problem by breaking down carboxylic compounds. Possible industry locations for the process under discussion in Japan would be steel, coal and brewery.

The control conditions for the process do require fairly sophisticated techniques. These are feed water pH and deoxygenation regeneration. At present fixed beds give short cycles. They are looking at simpler control procedures such as moving bed.

The resin will remove nitrate and there is some selectivity of nitrate over chloride. With wastewater feed very low levels of ammonia and nitrate were found in the effluent. At present it is still complex and not suited for small scale.

IV. CRITIQUE OF SESSION

Paper No. 65 describes newly developing technology and appeared to be somewhat original. The quality was very good.

The presenter of Paper No. 68 had great difficulty speaking English and, conversely, of being understood. The prepared discusser was quite impressed with the paper. This had the most scientific detail of the three papers in this session. Unfortunately, the author's difficulty with English reduced his effectiveness. The work appears original and its quality is very good. Only two people contributed to the floor discussion indicating the audience was not overly familiar with the area under discussion.

There were only two floor discussions for Paper No. 71 and they did not directly address the materials presented in the paper. A lack of floor discussion might be attributed to the fact that this was the last paper in the session and thus the Conference. Paper No. 71 mentions that organic fouling is a major problem and the presenter of the paper gave too little information even when asked directly on this subject. This seemed to be part of a series of papers covering this process. Therefore, it does not appear to be highly original; it is more like a progress report. However, the quality was good.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The results of Paper No. 65 apply directly to both water and wastewater fields. Since the magnetic resin and pipeline reactor have only advanced to the pilot plant stage, this concept should be reviewed to see where its priority and application should be.

The metal industry would be very interested in Paper No. 68. In addition, industrial wastes with metals are applicable. The concept of creating a method to reuse and recycle industrial wastes is commendable.

With regard to Paper No. 71, there was a feature article in *Environmertal Science and Technology* in its October 1976 issue covering ion exchange and included the Sirotherm Process for water as one of its major subjects (page 980). For wastewater the area is still developing and certainly could help solve U.S. water pollution problems in reuse.

I. SESSION

A. Theme of Session: Fixed Film Biological Contactors

B. Papers Presented: 60. Theory and Design of High-Rate Media Trickling Filters.
J. A. Oleszkiewicz (Poland)

63. Biological Rotating Disk Scale-up Design: Dissolved Oxygen Effects.
W. H. Chesner, A. H. Molof (USA)

II. REVIEWER

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B. Position and Affiliation: Professor of Environmental Engineering
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III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 60

The paper presents the development of a model to describe the performance of a high rate media trickling filter. The model is identical to a substrate removal model of the plug flow activated sludge if the trickling filter biomass is related directly to the specific surface area, i.e., activated sludge solids correspond to the specific surface area in biofilters. Some limited amount of the author's data as well as results from other workers are presented to verify the model. A general guideline for the design of high rate media trickling filter is also presented.

A.2 Paper No. 63

The author, in the paper presented, attempted to delineate a problem in the biological rotating disk scale-up design concerning only the dissolved oxygen transfer in the process. The data show a decrease in peripheral velocity resulting in a reducing overall dissolved oxygen concentration. However, peripheral velocity is related to disk diameter. Rotational velocity, independent of disk size, correlates much better with the reactor DO concentration than peripheral velocity. A model was presented to relate the DO at the first stage with rotational velocity and COD. The author, however, in his conclusion stated that rotational velocity is impractical to use as a design scale-up speed. This is mainly due to the fact that rotational velocity scale-up in a full-scale plant may lead to excessive shear forces on the fixed slime and power requirements. Peripheral velocity is still the design speed of choice today.

B. Prepared Discussions

B.1 The discusser, J. Roberts (Australia), raised a question on the author's interpretation of effluent changes in many diagrams presented in the paper. When recirculation is involved in the operation, an interaction of flow rate Q and feed concentration S_a on effluent S_e is in effect. The interpretation of the intercept to mean feed concentration would be erroneous. The discusser presented a mechanistic model which includes all parameters used by the author's model. In addition, the discusser's model includes a recirculation concentration parameter as well as an influent substrate inhibition function. More significantly, the model has separated the process variables, flow rate Q and influent concentration S_a from the plant or design variables, packing specific surface area, A, and packed height, H. The given model and the diagrams presented show clearly the advantage of the discusser's approach in that erroneous interpretations can be eliminated.

B.2 Two prepared discussions were presented. G. Rincke of the Federal Republic of Germany presented results which show an increasing of peripheral speed of disk results in larger values of the oxygen transfer coefficient, K_La. Similar to the author's work, the results show that smaller disks have higher oxygen transfer capabilities for the same peripheral speed. For a 3 m diameter disk turning at 15 rpm, the peripharal speed is 2.4 m/sec which may, according to the discusser, have detrimental effects on the slime layer due to the excessive shear force. N. W. Schmidtke of Canada commented on the author's work with a suggestion that the value of the paper can be greatly enhanced by stating more clearly the boundary conditions under which the author conducts his work. The author should study both the immersion depth as well as the wall effects. Although the system cannot be properly described in terms of Reynolds, Froude, Weber or power numbers, or even a combination of them, a calculation of the Reynolds' number is useful. Hartmann in 1967 has shown that at a Reynolds' number greater than 3×10^3, the effect of turbulence on biological reaction rate becomes negligible. The discusser also referred to his work on scale-up methodology for surface aerated reactors involving a simple functional power relationship between two independent variables of impeller diameter. It was suggested to the author that the same scale-up function, but involving a different power exponent, could be developed for the rotating disk system. Furthermore, the exponential value will indicate which forces predominate in the system. Theoretically the exponent is near 0.5 when gravitational forces predominate, 1.5 surface tension forces and at 2.0 viscous forces.

C. Floor Discussions

C.1 Several comments were offered from the floor. These include:

1. The author neither considered nor included the flow regime parameter in developing his model although the possibilities of turbulent flow, quasi-trubulent flow, and rippled laminar

flow have been mentioned. The possible incorporation of the Reynolds' number in a model was suggested.

2. A model of the first order equation may overlook the possible higher order and fractional order equations which could be more suitable in describing the complicated unit process of a high rate media trickling filter.

3. The thickness of the slime layer was not considered in the model.

4. The explanation of an abrupt change in direction of a straight line log S_e vs. the reciprocal of volumetric load (1/Z) was given by the author as an indication of an effluent concentration below which removal processes were slower. The explanation is not convincing.

It should be noted that neither the author nor the designated substitute was present to present the paper and to make the concluding discussion. A lively discussion of the subject inside and outside of the meeting room was absent.

C.2 The following comments and discussions were initiated from the floor:

1. A study in the Philippines indicates that the oxygen transfer mechanism should be divided into two parts, one from the atmosphere to the slime layer or the part of the disk emerging from the liquid, and the other from the atmosphere to the liquid and then to the submerged slime layer. The two transfer mechanisms are different. The second part is related to the Reynolds' number. The black-box approach taken by the author without considering the basic mechanism in mass transfer contributes to one more equation among nearly one hundred others which are presently available. The author's finding of poor COD removal at 2 mg/ℓ or lower concentrations of DO in the liquid was also questioned by the discusser since there is evidence to show consistently a high performance by rotating biological contactors with 0.1 to 1 mg/ℓ DO concentration in the system.

2. The validity of scale-up based on dissolved oxygen is questioned because recirculation is often practiced in rotating biological contactor operation just as in the operation of trickling filters. When recirculation is in effect, the combined influent flow has a much higher DO concentration and a lower organic concentration than the influent alone. The relationship of DO with the rotational speed of the disk as well as the organic substrate concentration, as is expressed by the author's model, does not hold any longer unless recirculation parameter is included in the model. It has also been observed in pilot plant studies that the rotating biological contactors perform as a combination of biological film filter and a suspended growth reactor. The

removal of organic substrate by the suspended biomass is significant. It is suggested that separate considerations are given in substrate removal by the slime layer and by the suspended growth in order that the true mechanism and kinetics of removal can be understood.

3. The author used single disks for his study. No scale-up consideration is given to the effect of banks of disks on oxygen transfer as compared to single disks.

IV. CRITIQUE OF SESSION

Since Paper No. 60 was not presented by the author, a disappointment could be felt among the participants in the meeting. Much of the questioning directed at the author by the discussers went unanswered. Much old data, either by the author's own work or by other workers, were presented in the paper. The model and its discussion have been presented elsewhere by the author as it was so stated in the paper. Symbols in many equations presented have not been properly identified, leading to unnecessary guessing by the readers. The design guidelines are too general to serve any useful purpose.

The author's model, originating from a basic substrate removal kinetics equation, does not show any new concept or incorporate any new parameter when compared with a multitude of equations long available for design purposes in Europe as well as in the United States. A designer needs to carry out extensive pilot scale tests to derive the removal rate coefficient, k, under various operating conditions. Even so, the uncertainty of uneven distribution of slime in the media, decrease of the effective surface area, A, and uneven distribution of liquid over the media surface could be critical in scale-up for which the author's paper offers no help.

The discusser's model (Equation 19) incorporates the recirculation flow concentration and an influent substrate function. Two areas of improvement over the author's model can be recognized. Firstly, interaction of flow rate Q and feed concentration S_a can be handled properly in preparing the performance prediction diagram. Secondly, the inhibition function allows a correction of regression of substrate degradability when the liquid is recirculated many times through the filter. Nevertheless, much of the criticism on the author's model also applies to that of the discusser. Most significantly missing from these two models are slime thickness and biologically active surface area per unit filter volume. Unfortunately the difficulty in measurement of these two parameters prohibits their incorporation into the prediction or design models.

Much discussion took place in the meeting following the presentation of Paper No. 63. The first question on this research work is whether scale-up based on dissolved oxygen has any practical value. A pilot plant study at the University of Rhode Island has shown high DO in latter stages of biological rotating disk systems in severe overloading (over supply of organic substrate) and no recirculation circumstances. When recirculation applies, as it is a standard practice for trickling filter and biological rotating disk operations, even the first stage has high DO concentration in organic overloading situations.

The author recognized the importance of rotational velocity as a scale-up design parameter but decided against its use because it is impractical to use. Furthermore, two discussers adequately point out that the oversimplified approach taken by the author overlooks many important factors such as banks of disks vs. single disks, wall effects, disk submergence, flow regime criteria such as Reynolds' number, possible use of a functional power relationship which enables a designer to recognize the predominant force in the system among the gravitational, surface tension, and viscous forces.

Both papers present an empirical approach in an attempt to deal with complex problems. It is generally accepted that the complexity of biological contactor (both fixed film and rotating disks) processes are such that theoretical models have proved impractical for design purposes. On the other hand, empirical models cannot be extrapolated beyond the operating conditions and, to some degree, the media (type, configuration, and method of packing) for which they were devised. A theoretical model is circumscribed by assumptions under which it is expected to follow observed behavior. In general many restrictive assumptions can only be met in laboratory experiments specially designed for the purpose. Theoretical development proceeds by relaxing these restrictions in turn, to obtain an understanding of the overall system through understanding the individual processes of which it is comprised. The resultant understanding of basic behavior aids the practitioner when troubleshooting, designing or operating, particularly under conditions for which little or no previous experience is available.

In contrast, an empirical model makes little pretense of representing individual phenomena, since its purpose is to relate operating input and output variables to each other. Accumulated experience is correlated so that it is available, in reduced form, to the practitioner who expects accuracy under the conditions for which the information was gathered but who accepts risks outside these regions.

It follows that a theory must always be qualified by its simplifying assumptions and that an empirical equation must likewise be qualified by the conditions prevailing at the time the data were generated. It is in this spirit that the quality of both papers should be judged.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

For the paper on the high rate media trickling filter, an empirical model is offered. The practitioners can be benefitted by applying the model to design. It is unfortunate that the conditions under which the data were gathered are not specified. However, much of the data presented in brief forms in the paper have been presented in greater detail elsewhere and such information can be obtained from references cited by the author (Ganczarczyk, 1960; Bruce and Merkens, 1973; Oleszkiewicz, 1974, 1975). Consequently design engineers in America can find use of the model under certain circumstances.

Much of the problem of scale-up has not been solved. The performance of a trickling filter is greatly dependent on the distribution and thickness of the active biological film. The empirical models presently available cannot relate the process variables, flow rate Q and influent concentration Sa, to the distribution and characteristics of the biological film. Research in this direction is needed.

The authors of the paper on rotating biological contactors did not present a working model with peripheral speed. The paper does point out the significance of taking into consideration the relative rotational velocity differences in scale-up. Presently there is a great variety of rotating contactors on the market with different physical and mechanical features. Coupled with the fact that the system works as a combination of a biological filter process and a suspended growth process, the difficulty of scale-up is easily recognized. Recirculation of effluent in controlling the thickness of biological film and in distributing the active biological film more evenly throughout all stages of the process is perhaps the most important feature of the process operation. Future research work should be directed to include these considerations in either the development of theoretical and empirical models for design or the development of a scale-up procedure for the process.

I. SESSION

A. Theme of Session: Uptake, Exchange Kinetics, Transport

B. Papers Presented:

66. Uptake of Americium-241 by Algae and Bacteria.
J. P. Giesy, Jr., D. Paine (USA)

69. Nutrient Exchange Kinetics in Water Sediment Interface.
C. P. C. Poon (USA)

72. Mercury Transport Interacting with Bed Sediment Movements.
A. Kudo, D. R. Townsend, D. R. Miller (Canada)

II. REVIEWER

A. Name: John Cairns, Jr.

B. Position and Affiliation:
University Distinguished Professor
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 66

The important feature of this paper is that it was concerned with one of the most toxic substances known to mankind. Another interesting point was the surprisingly similar results in uptake for both pure cultures and aufwuchs communities.

A.2 Paper No. 69

The major point of this paper was that there was more phosphorus coming out of the mud in very polluted areas than the inputs from all other sources combined.

A.3 Paper No. 72

This paper presented a fairly detailed study of the mercury distribution, transport and transfer (including seasonal effects in all categories) in an aquatic ecosystem. Kudo feels he can estimate both distribution and transport in rivers.

B. Prepared Discussions

B.1 J. Slade (UK) pointed out how unlikely it was to have in a single institution both talent and facilities necessary to carry out such a study (this suggests confirming data not likely to be generated).

B.2 W. Stumm (Switzerland). The most serious criticism was that Poon paid no attention to the chemical characteristics of the interstitial water. The second was that over time, sediments can be either a sink, or a source of phosphorus, manganese, etc. and understanding which depends on the redox potential.

B.3 T. Sueiski (Japan). Mostly complimentary review. Pointed out that the paper only mentioned 75 samples while the research actually had thousands.

C. Floor Discussions

C.1 No significant floor discussion due probably to the almost total ignorance of the audience of americium.

C.2 A substantitive comment by Horne:

1. Is rate of sedimentation constant over geologic time?
2. Should Poon have used shock loads?
3. If the supply rate from sediments was greater than from sewage and other sources this can only be a temporary situation.

Reply - This was only a limited simulation with a gross check on the field situation and there was no attempt to study the mechanism of tieup of nitrogen and phosphorus. Poon also assumed a constant rate of sedimentation although he realized this was probably not actually true.

IV. CRITIQUE OF SESSION

The paper by Giesy (No. 66) may well be the most important of the conference in terms of identifying a problem of major political and social concern. The audience reaction was cautious as is typically the case when a professional group is faced with an unexpected problem of possible major significance. Giesy's research and presentation were generally acclaimed despite the paucity of discussion. Poon and Kudo gave good first approaches to systems dynamics problems.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Concerns identified by Giesy's paper deserve serious immediate attention, i.e., how to cope with ultra toxic materials. It would be irresponsible not to get more information about the biological effects of americium. The other papers provide useful information and examples of how such monitoring can be carried out. They also identify pitfalls in such studies.

CHAPTER III

OVERVIEW OF PERTINENT CONFERENCE DEVELOPMENTS

In this chapter, pertinent developments at the Conference as reported by individual participants are briefly summarized and categorized. The Chapter represents primarily a summary of Chapter II; however, other observations made by individual participants regarding international developments of potential interest to EPA, not emanating from the formal program of the Conference, are indicated.

Developments at Formal Sessions

This section highlights the individual reports contained in the previous Chapter by reviewing the more significant observations and conclusions according to various categories of water pollution research interest. In each case, comments are identified by the paper number or workshop title to which the observations relate. Comments included here may not necessarily be contained in the formal papers but may have developed from discussions at the Conference. Paper numbers and workshop titles are included to facilitate reference to the more extensive analyses of Conference developments included in Chapter II. By referring to the paper or workshop of interest in the Table of Contents and Key to Reviews, the location of the corresponding discussion in Chapter II may be determined.

Virus and Pathogenic Organisms --

There was appreciable interest at the Conference in work previously reported in Science and elsewhere indicating a higher incidence of enteric communicable diseases in kibbutzims in Israel which practice spray irrigation of partially treated, non-disinfected oxidation pond effluent as compared with kibbutzims practicing no form of wastewater irrigation (Paper No. 1). Doubts were expressed (Workshop on Land Treatment), however, about the application of the epidemiological results to American practice because of the higher background level of enteric disease in Israel, the greater degree of concentration of organisms in wastewater, and the lower degree of treatment provided prior to spraying. Additionally, a recent study of absentee records from employees of the Werribee Farm (Melbourne's sewage farm) in Australia showed a lower rate of absenteeism than for other employees of the same organization, the Melbourne and Metropolitan Board of Works (Workshop on Land Treatment). The need for collecting additional epidemiological data in the United States on the incidence of infectious diseases among both waste treatment plant personnel and residents in the immediate vicinity of wastewater treatment plants was suggested (Paper No. 1).

The unreliability of a bacterial virus as a model of the behavior of an enteric virus was emphasized (Paper No. 7). Confusion concerning reported information on virus movement in soil systems was noted and research to clarify the matter was suggested (Workshop on Land Treatment). Because of the resistance of certain enteric viruses to environmental conditions and certain disinfectants, acid-fast organisms (e.g., *Mycobacterium fortuitum*) and yeasts (e.g., *Candida parapsilosis*) may be candidate indicator organisms for enteric viruses (Paper No. 10). In this same paper, ozone bubbles were reported to give a higher degree of inactivation than an ozone residual alone.

Toxic Materials and Monitoring --

Serious concern was expressed about the extreme toxicity of Americium 241 (Paper No. 66). It was apparent that little is known about the environmental significance of what may be one of the most toxic materials known to man.

Monitoring of the toxicity of wastewater discharges based on measurement of fish respiration rates was reported (Paper No. 54). The response limit of fish sensors was felt to lie between 5 and 10 percent of the 48-hour lethal limit and was considered to be a reliable technique for automatic monitoring systems. A means for obtaining rapid evaluation of fish toxicity by concentrating toxicants contained in samples by freezing techniques was discussed (Paper No. 58).

Sludge Management --

In contrast to the United States (Paper No. 32), it was reported that appreciable Japanese experience with pyrolysis may be available (Paper No. 29). It appears that a wealth of information on this subject may be available in Japan which could help to accelerate American efforts on pyrolysis.

The need for recognizing the reversible nature of lime stabilization of sludge due to pH reduction was emphasized (Paper No. 26). A Norwegian experience with hydrolysis of organic matter at high pH and resulting high BOD values in the filtrate from lime stabilization sludges was reported. Greater consideration of the effect of stabilization and other sludge treatment processes on sludge characteristics and resulting implications with regard to the land disposal was suggested (Workshop on Ultimate Disposal of Sludges).

It was indicated that present practices do not permit reliable design of sludge thickeners on the basis of simple laboratory testing (Paper No. 23). It was considered necessary to develop design procedures which adequately account for the role of filtration and particle deformation in sludge thickening.

Integrated Pollution Control Systems --

Conference participants were interested in a system for using fly ash from air pollution control scrubbers for wastewater clarification (Paper No. 28). Substantial savings in the cost of coagulating chemicals was indicated, and data were presented indicating that the heavy metals contained in the fly ash were not released to the wastewater. A need was identified at the Conference (Paper Nos. 37, 40, 43, and 46) for more effective integration of physicochemical wastewater treatment processes with conventional (or novel) biological wastewater treatment techniques. Opportunities for achieving higher degrees of treatment while avoiding excessive expenditures were felt to be available.

Advanced Wastewater Treatment --

Advantages of surface aerated equalization ponds in reclamation systems were emphasized (Paper No. 33). In addition to affecting equalization of water quality, the ponds improved the efficiency of ammonia stripping towers, reduced the degree of calcium carbonate supersaturation, allowed for some destruction of pathogens, and facilitated breakpoint chlorination.

Experiences in South Africa verifying the advantage of adding lime in a recycling stream as compared to direct lime addition were reported (Paper No. 37). The practice allows for crystal seeding and increases reaction time.

An interesting report was presented on the use of magnetized resin in a moving bed ion exchanger (Paper No. 65). A dramatic increase in settling rate occurs upon magnetization. The process, currently being developed in Australia, is in the pilot plant stage.

Ocean Pollution --

Based on British experience, one author concluded that primary sedimentation prior to ocean disposal of effluent was not considered to be justified (Paper No. 21). The environmental degradation associated with sludge disposal from such facilities was felt to exceed the improvement in ocean water quality. Primary treatment may be justified with sewages of high grease content.

Land Treatment --

There was appreciable interest at the Conference in the Werribee Farm Land Treatment System used by the City of Melbourne. Raw sewage is applied by flood irrigation at a rate of about 105 cm/yr, and the land is used for grazing by beef cattle and sheep. Beef carcasses are inspected prior to sale, and no health problems have been identified (Workshop on Land Treatment).

Miscellaneous --

Lining of sewer pipes for corrosion control, using resin impregnated terylene, was reported to be practiced in Singapore (Paper No. 44). Five to 15 mm linings are produced which are rigid and self supporting.

A novel means for the surface water quality modeling was presented by a French researcher (Paper No. 8). A sophisticated statistical transformation model is used to manage large water quality data matrices.

A need was suggested for improved analytical techniques for measurement of oils and greases (Paper No. 48). A need exists for distinguishing between oils and greases of vegetables, animal, and "mineral" origin.

Developments Outside of Formal Sessions

Much of the beneficial exchange of technical information which occurs at professional meetings takes place outside of the formal meeting rooms, and at international conferences the opportunities for effective information transfer by this means are considerable. Participants in the development of this report were asked to submit comments obtained from such interactions with water pollution researchers from other nations. Several of the participants also submitted comments on the value of the international exchanges on water pollution research. These reactions and items of possible interest to EPA which were not a part of the formal Conference program are summarized in this section.

Nature of the Conference --

One participant, a veteran of several IAWPR biennial conferences, indicated a general improvement in the quality of papers presented at Sydney. Another participant related a general feeling he perceived among Conference participants that inadequate basic research in water quality control is being performed globally.

One participant remarked that participation in the Conference had been worthwhile if only because "it was most reassuring to verify that my appraisal of the research progress of others in my field was accurate." The same participant indicated that as a result of the Conference, he felt that he would now have far better access to unpublished data of foreign researchers. Perhaps the following statement best summarizes the remarks made by many participants concerning the value of exchange of technical information with water pollution researchers in other nations:

> "In general, the research papers reflected the needs of the respective nations conducting the research. For example, water reuse was dominant in the contributions from Israel and South Africa, while secondary and advanced treatment reflected research in North America and Europe. One value of this type of conference is that research from one nation can be meaningfully discussed and contributed to by researchers from other nations. This was amply demonstrated in many of the sessions where the experience from many nations in similar and allied areas greatly enhanced the technical value of the primary paper. To the writer's knowledge, this is the only forum in water pollution research where this type of interaction is achieved."

Health Related Research --

One participant expressed disappointment at the small number of health-related papers on the technical program but felt that his conviction that health effects is an area which deserves far more attention of researchers in the United States was verified by the widespread concern over health-related problems expressed in personal conversations at the meeting. A startling claim of possible transfer of antibiotic resistance from coliforms to pathogenic organisms was related by a participant from New Zealand. He indicated that he had observed such a transfer even between species, genera, and families. It was suggested that several recent outbreaks of typhoid fever might be attributed to this phenomenon.

A Brazilian researcher discussed the survival of enteric viruses and coliforms in sediments around ocean outfalls. He noted that they had much longer survival times in sediments than in overlying water and indicated the possibility of resuspension of pathogenic microorganisms and viruses.

Concern with the report (Paper No. 1) of epidemiological evidence of aerosolization and dispersion of enteric microorganisms during spray irrigation in Israel was not confined to the technical sessions. One of the participants indicated a conversation with a researcher from Israel in which it was indicated that the disease-causing organisms could have been transported to the villages on the clothing of field workers who were exposed to the sprayed effluents in the fields or on the vehicles used on the fields.

Because of the location of the Conference, the Werribee Farm near Melbourne which has been practicing waste application on land for 80 years was a frequent topic of discussion. One concern which came from private conversations about the Werribee Farm was the transmission of Taenia in the meat of these cattle. A significant point was the development of a vaccine which can be injected into the animals to immunize them against Taenia.

Ocean Disposal --

Because of national differences in practices with regard to wastewater and sludge disposal to the ocean, this topic was frequently discussed in informal sessions, particularly the need for even primary treatment of wastewater prior to ocean disposal. One participant reported a general consensus, from informal discussions, of a lack of incentive to remove nutrients prior to ocean disposal; but pretreatment for heavy metal removal might be considered.

Scale of Facilities --

A participant reported on discussions indicating concern with a tendency for increased regionalization in wastewater treatment. The gist of the concern was that as the scale is increased, so are siting problems and transportation costs; and the problem of disposing of sludge and reusing effluent are magnified. When resource recovery from wastewater is a societal goal, dispersal of treatment facilities may have some merit.

Wastewater Reuse --

The following quote from a participant summarizes the general thoughts on wastewater reuse by several participants:

> "Wastewater reuse, rather than simply receiving water quality control, appears to be more and more an issue of global concern with respect to water pollution research. Water shortage in many areas of the world, coupled with increasingly stringent effluent quality requirements, are bringing heretofore separated aspects of wastewater treatment technology and water development and treatment technology closer together. De facto reuse exists; planned reuse is a near-term reality. This will likely have profound effects on the philosophy - and technology - of wastewater treatment."

APPENDICES

Appendix I

CONFERENCE PROGRAMME

QUICK REFERENCE PROGRAMME OF ALL ACTIVITIES

SATURDAY, OCTOBER 16

12 noon – 8.00 p.m.		REGISTRATIONS – Wentworth Hotel

SUNDAY, OCTOBER 17

9.00 a.m. – 5.00 p.m.		REGISTRATIONS – Wentworth Hotel
Morning		EXCURSION E.1 – City sights
Afternoon	4.30 p.m.	OPENING CEREMONY – Sydney Opera House
Evening	6.30 p.m.	OFFICIAL RECEPTION – Sydney Opera House
	7.30 p.m.	CONCERT – Sydney Opera House

MONDAY, OCTOBER 18

Morning	9.00 a.m.	FIRST TECHNICAL SESSION – Wentworth Hotel
		EXCURSION E.2 – Northern Beaches
Afternoon	2.00 p.m.	SECOND TECHNICAL SESSION – Wentworth Hotel
	4.35 p.m.	FIRST SHOWING – I.A.W.P.R. film
		EXCURSION E.3 – Wildlife Sanc.
Evening		EXCURSION E.4 – Sunset and Starlight

TUESDAY, OCTOBER 19

Morning	9.00 a.m.	THIRD TECHNICAL SESSION – Wentworth Hotel
	9.15 a.m.	HARBOUR CRUISE (For Accompanying Persons)
Afternoon	2.00 p.m.	FOURTH TECHNICAL SESSION – Wentworth Hotel
Evening	6.30 p.m.	AUSTRALIANA BARBECUE – A.J.C. Randwick Racecourse

WEDNESDAY, OCTOBER 20

Morning	9.00 a.m.	FIFTH TECHNICAL SESSION – Wentworth Hotel
All Day		EXCURSION E.5 – Blue Mountains and Jenolan Caves
		EXCURSION E.6 – Canberra

WEDNESDAY OCTOBER 20, Continued

Afternoon	2.00 p.m.	SIXTH TECHNICAL SESSION – Wentworth Hotel
	4.30 p.m.	SECOND SHOWING – I.A.W.P.R. Film
		EXCURSION E.7 – Wildlife Sanc.
Evening		Free

THURSDAY, OCTOBER 21

Morning	9.00 a.m.	SEVENTH TECHNICAL SESSION – Wentworth Hotel
	9.30 a.m.	VISIT TO ARGYLE CENTRE AND PICNIC LUNCH (For Accompanying Persons)
Afternoon	2.00 p.m.	FINAL TECHNICAL SESSION – Wentworth Hotel
Evening	7.30 p.m.	CONFERENCE BANQUET – Wentworth Hotel

FRIDAY, OCTOBER 22

Morning	8.00 a.m.	TECHNICAL INSPECTION TOUR T.1 – Malabar and Southern Beaches
	8.00 a.m.	TECHNICAL INSPECTION TOUR T.2 – Shell Oil Co., Clyde
		EXCURSION E.8 – Taronga Park Zoo
All Day		EXCURSION E.9 – Hunter Valley
Mid-day	12.30 p.m.	FAREWELL HOUR – Wentworth Hotel
Afternoon	1.30 p.m.	TECHNICAL INSPECTION TOUR T.3 – Warriewood and Northern Beaches
	1.30 p.m.	TECHNICAL INSPECTION TOUR T.4 – Castle Hill and Koala Park

SATURDAY, OCTOBER 23

Morning		CONTINUING EDUCATION COURSE Commences Melbourne

SUNDAY, OCTOBER 24

Morning		POST CONFERENCE TECHNICAL INSPECTION TOUR COMMENCES

IAWPR
SYDNEY
1976
8
INTERNATIONAL
CONFERENCE

PROGRAMME OF TECHNICAL & SCIENTIFIC SESSIONS & WORKSHOPS

Conducted at the WENTWORTH HOTEL

Monday October 18 until
Thursday October 21

ENQUIRIES CONCERNING ALL ASPECTS OF THE TECHNICAL & SCIENTIFIC PROGRAMME SHOULD BE REFERRED TO MR. R. R. ASH AT THE TECHNICAL SESSIONS OFFICE, MEZZANINE FLOOR, WENTWORTH HOTEL.

CONDUCT OF
SESSIONS & WORKSHOPS

GENERAL ARRANGEMENTS

All sessions and workshops will be held in the Conference meeting rooms, Mezzanine Floor, Wentworth Hotel, from Monday October 18 to Thursday October 21, inclusive.

The conduct of the sessions will be as follows:

1. GENERAL ARRANGEMENTS

1.1 All Conference sessions on Monday 18 to Thursday October 21 will be at the Wentworth Hotel, Sydney, commencing at 9 a.m. and at 2 p.m.

1.2 Three Halls, A, B and C will be in use concurrently except for the Workshops on Tuesday and Thursday when only two Halls, A and B, will be in use.

1.3 Simultaneous interpretation will be operating in English, French and German in Halls A and B. Sessions in Hall C will be conducted in English only.

2. CONDUCT OF SESSIONS OTHER THAN WORKSHOPS

2.1 Each of these sessions will be of 45 minutes duration.

2.2 The paper will be circulated in advance and be taken as read. Authors will be allowed ten minutes to introduce the paper.

2.3 The Chairman will call the nominated discusser who will be allowed five minutes to introduce the discussion.

2.4 The Chairman will then call discussers from the floor calling first those who have notified their intention to speak by completing a discussion slip. No discusser will be entitled to speak for more than three minutes save at the discretion of the Chairman.

2.5 No later than five minutes before the end of the session the Chairman will close the discussion to give the Author or Authors opportunity to reply to the discussion.

2.6 Nominated discussers and all subsequent discussers must confine their remarks to the subject of the paper; the Chairman has power to halt discussion which goes beyond the confines of the subject.

3. CONDUCT OF WORKSHOPS

3.1 Each Workshop will be of 90 minutes duration.

3.2 The objects of the workshops are to promote informal discussion on subjects (as per the Programme) of current interest, to identify topics for further discussion or investigation and to prepare a report to be included in the Conference Proceedings.

The Conveners have been responsible for nominating speakers who will introduce the discussion.

No papers will be circulated in advance.

3.3 The Convener will open the workshop promptly and will take no more than five minutes to introduce the general theme of the workshop.

3.4 The Convener will then call upon the nominated speakers in turn to make their points. The Convener will allow a total of 30 to 40 minutes for this part of the workshop, allocating time per speaker, accordingly.

3.5 The Convener will then call discussers from the floor giving priority to those who have notified their intention to speak by completing and handing in a discussion slip. No discusser will be entitled to speak for more than three minutes save at the discretion of the Chairman.

3.6 The discussion will be terminated fifteen minutes before the end of the session to enable the nominated speakers to reply to the discussion and the Convener to summarise the conclusions of the workshop.

4. PROCEEDINGS

No verbatim report will be made of the proceedings. Contributors to the proceedings who wish their contributions to be recorded must send three copies in typescript in English to the Secretary-Treasurer, IAWPR, Chichester House, 278 High Holborn, London WC1 U.K., to reach him not later than November 30, 1976. The Editor reserves the right to accept, reject or edit these contributions for publication in the Conference Proceedings to be printed in "Progress in Water Technology".

PREPRINTS OF PAPERS

Registrants who did not request that their copy of the Preprints be sent to them prior to the Conference can take delivery of their copy at the TECHNICAL SESSIONS PROGRAMME OFFICE each day of the Conference between 8.30 a.m. and 5 p.m.

MONDAY MORNING

	HALL A	HALL B	HALL C
	1. Spray Irrigation with Wastewater: The Problem of Aerosolization and Dispersion of Enteric Microorganisms. E. Katzenelson, B. Teltch, H.I. Shuval (Israel)	2. Great Lakes Water Quality Agreement. James P. Bruce, Peter M. Higgins (Canada)	3. Comparative Evaluation of Commercial Polyelectrolytes for Flocculating Alum Precipitated Domestic Wastewater. Andrew Benedek, John L. Bancsi (Canada)
9.00–9.45 a.m.	Chairman: B. Hanes (USA) Reporter: R.A. Canham (USA) Discusser: C. Lue-Hing (USA)	Chairman: A. Hansen (Sweden) Reporter: E. Rosen (Sweden) Discusser: K.W. Lewis (Australia)	Chairman: P. Benedek (Hungary) Reporter: C.P. Fisher (Canada) Discusser: H.N.S. Wiechers (South Africa)
	4. Virus Retention by Soil. K.V. [illegible] (India)	5. Localised Destratification of Large Reservoirs to Control Discharge Temperatures. Frank L. Burns (Australia)	6. Treatment of Chlorinated Hydrocarbons Wastewater by Activated Carbon Adsorption with Steam Regeneration. Yerachmiel Argaman, Giovanni M. [illegible] (Israel)
9.50–10.15 a.m.	Discusser: H.I. Shuval (Israel)	Discusser: L.H. Jones (S. Africa)	Discusser: F. Middleton (USA)
	7. The Removal of Viruses by Slow Sand Filtration. S.F.B. Poynter, J.S. Slade (Great Britain)	8. A Multidimensional Analysis of the Results of the French 1971 Surface Water Quality Network Control in the River Basin "Seine-Normandie". Y. Le [illegible], R. Pinon, A. [illegible] (France)	9. A Fundamental Study of the Removal of Polynuclear Aromatic Hydrocarbons from Water During Chlorination. Roger Perry, R.M. Harrison (Great Britain)
11.00–11.45 a.m.	Chairman: H. McFie (Australia) Reporter: L.F. Scragg (Australia) Discusser: L. Coin (France)	Chairman: G.D.W. Roberts (UK) Reporter: J. Gallard (UK) Discusser: J.J. Wright (Australia)	Chairman: D.E. Weiss (Australia) Reporter: N. Norman (Australia) Discusser: T.E. Larson (USA)
	10. Virus Removal in Activated Sludge Sewage Treatment. V. Chalapati Rao, S.B. Lakhe, S.V. Waghmare, Pushpa Dube (India)	11. Hydrodynamics of Bubble Plumes and Oxygen Absorption in Stratified Impoundments. F. Rayyan (Saudi Arabia), R.E. Speece (USA)	12. Chromium Removal with Activated Carbon. Jung I. Kim, John Zoltek, Jr. (USA)
11.50–12.35 p.m.	Discusser: J.F. Malina (USA)	Discusser: P.A. Krenkel (USA)	Discusser: B.W. Van Vliet (South Africa)

NOTES

MONDAY AFTERNOON

HALL A

13. Nitrogen, Phosphorus and Virus Removal from Sewage Water During Land Filtration.
J. Clarence Lance, Charles P. Gerba (USA)

[illegible]–
[illegible]p.m.
Chairman: W. Gujer (Switzerland)
Rapporteur: H.I. Shuval (Israel)
Discusser: C. Lue-Hing (USA)

16. Faecal Coliforms and Faecal Streptococci: A Statistical Comparison using Data from England and Papua New Guinea.
R. Feachem, [illegible], E. [illegible] (Gt. Brit.)

[illegible]–
[illegible]p.m.
Discusser: D.J. Lowe (Australia)

19. The Effect of Ozone Bubbles on Disinfection.
Shaukat Farooq, Richard S. Engelbrecht, Edward S.K. Chian (USA)

[illegible]–
[illegible]p.m.
Discusser: P. Stumm (Switzerland)

HALL B

14. Technical Requirements and Analysis Methods for Evaluating the Environmental Consequences of Groundwater Contamination.
R. William Nelson (USA)

Chairman: C. Boeuf (France)
Rapporteur: C. Gomella (France)
Discusser: B. Rygaard (Norway)

17. Pilot Plant Investigation of the Evolution of Various Pollutants During Artificial Recharge of an Aquifer by a Basin.
Michele Rian, Joel Mallevialle, Jean-Claude [illegible] (France)

Discusser: B.J. Lyons (Australia)

20. Hydrochemical Effects of Waste Percolation on Groundwater in Basalt near Footscray, Victoria, Australia.
[illegible] (Australia)

Discusser: W.R. Harvey (S. Africa)

HALL C

15. Sedimentation of Dispersed Oil in Surface Waters.
B. Thiel, Werner Stumm (Switzerland)

Chairman: A.L. Downing (UK)
Rapporteur: R. Perry (UK)
Discusser: To be Announced

18. The Application of a Two-layer Time-Dependent Model to Pollution Assessment and Control in a Short Stratified Estuary.
[illegible], P.G.H. Pryor (Australia)

Discusser: D.R. [illegible] (UK)
Presented by G.E. Eden (UK)

21. Preliminary Design of Ocean Outfall at [illegible] of Settling Water.
[illegible], T.J. [illegible], R.B. Moore (Australia)

Discusser: D. Munro (UK)
Presented by G.E. Eden (UK)

NOTES

TUESDAY MORNING

	HALL A	HALL B	HALL C
	Workshop — Current and Future Marine Pollution Problems Convenor: E.A. Pearson	Workshop — Ultimate Disposal of Sludges, Toxic Wastes and Strong Organic Liquors Convenor: G.E. Eden	
9:00 – 10:30 a.m.	Reporter: To be announced Speakers: 1. J.D. Isaacs (USA) Ecological Aspects of Pollution 2. T.C. Griffing (Canada) Arctic Offshore Oil Exploration 3. H. Caspers (Fed. Rep. Germany) Benthic Research and Sludge Dumping	Reporter: R.K. Chalmers (UK) Speakers: 1. L. Ulmgren (Sweden) Disposal of Industrial Sludge 2. D. Tabasaran (Fed. Rep. Germany) Pyrolysis of Waste & Sewage Sludge 3. G.A. Carthew (Australia) Lime Recovery from PCT Sludges 4. B. Lynam (USA) Solid Disposal and Utilisation	
	22. Dynamic Nature of Non-Dying Biological Suspended Growth Systems Keith L. Murphy, Paul M. Sutton, Bruce E. Jank (Canada)	23. Continuous Gravity Thickening of Sludges Peter Kos (USA)	24. Dissolved-Air Flotation in Activated Sludge J. Bratby, G. v. R. Marais (South Africa)
11:00 – 11:45 a.m.	Chairman: E.J. Hall (S. Africa) Reporter: F.F. Kolbe (S. Africa) Discusser: A. Balaban (Israel)	Chairman: R. Engelbrecht (USA) Reporter: E.R. Baumann (USA) Discusser: Y. Argaman (Israel)	Chairman: L. de Henry (Australia) Reporter: K. Chiller (Australia) Discusser: A. Bast (France)
	25. Design of a P-removing Activated Sludge Process with the Aid of Dynamic Simulation W. Gujer (Switzerland)	26. Dewatering Properties of Lime Stabilized Sewage Sludges B. Paulsrud, A.S. Eikum (Norway)	27. Variability of Temperature and other Process Parameters — A Time Series Analysis Sludge Plant Data Dr. Kwan-Chow Lin, Dr. Sam R. Hester (Canada)
11:45 – 12:30 p.m.	Discusser: A.L. Downing (UK)	Discusser: R.I. Dick (USA)	Discusser: W.W. Eckenfelder (USA)

NOTES

TUESDAY AFTERNOON

HALL A

28. An Integrated Pollution Control System: Combined Clarification of Wastewater and Incinerator Scrubber Effluent and Utilization of Clarified Effluent for Scrubbing of Stack Emissions.
R.J. Baker, Jr., F.L. Smith (USA)
M. Rebhun (Israel)

2.00–
2.45 p.m.
Chairman: D. Stephen (USA)
Reporter: P. Balmér (Norway)
Discusser: J. Barnard (S. Africa)

31. Design Approach for Effluent Variability Removal in Wastewater Treatment Systems.
Vladimir Novotny (USA)

2.45–
3.30 p.m.
Discusser: D.S. Berger (USA)

34. The Integration of Wastewater Treatment with Water Reclamation.
Lucas R.J. Van Vuuren, Willem R. Ross, Jan Prinsloo (South Africa)

3.30–
4.15 p.m.
Discusser: J.J. Bright (Australia)

HALL B

29. Studies on Pyrolysis Process of Sewage Sludge
T. Mgimu, K. Takao, M. Kanaya, M. Hosaka (Japan)

Chairman: S. Iwai (Japan)
Reporter: T. Sueishi (Japan)
Discusser: B.W. Ellis (Canada)

32. Combined Disposal of Sewage Sludge and Solid Wastes by the Pyrolytic Process.
N. Breitz, R.A. Lockwood, R.R. Bowerman, K.Y. Chen (USA)

Discusser: G. Lu [illegible] (USA)

35. Disposal of Sludge Using Solid Wastes as Fuel with Resource Recovery and Creation of Gas End Product for Utility Use.
Ivan L. Bogert, Everett E. Greene (USA)

Discusser: M. Hosaka (Japan)

HALL C

30. Comprehensive Temperature Model for Aerated Biological Systems.
Yerachmiel Argaman, Carl E. Adams, Jr. (USA)

Chairman: R.L. Sanks (N. Zealand)
Reporter: D. Brockett (N. Zealand)
Discusser: J. Hollo (Hungary)

33. The Efficiency of an Equalization Pond in a Water Reclamation Scheme.
Bert R. Van Solt, Herman N.S. Wiechers, Oliver O. Hart (South Africa)

Discusser: P. Benedek (Hungary)

36. Scale-up Methodology for Surface Aerated Reactors.
Norbert W. Schmidtke (Canada)
Janos Horvath (Hungary)

Discusser: F.F. Kotze (S. Africa)

NOTES

WEDNESDAY MORNING

	HALL A	HALL B	HALL C
	37. Investigations into the Lime Precipitation of Raw Municipal Wastewater. David Jenkins, F.W. Lee (USA)	38. Simulation of Design Storms with Probable Distributions in Time and Space for Storm Drainage Systems. F. Sieker (Germany)	39. [illegible] Plant Treatment – Comparison of Cost and Degree of Treatment. Henryk Melcer, Paul N. McFarlane (New Zealand)
9.00 – 9.45 a.m.	Chairman: E. Kuntze (Fed. Rep. Germany) Reporter: K.R. Imhoff (Fed. Rep. Germany) Discusser: L.R.J. Van Vuuren (S. Africa)	Chairman: J. Hollo (Hungary) Reporter: P. Benedek (Hungary) Discusser: T. [illegible] (Japan)	Chairman: J.D. [illegible] (Canada) Reporter: T. Davey (Canada) Discusser: J.L. Pretorius (S. Africa)
	40. Calcium Carbonate and Magnesium Hydroxide Solubility Product Values for Heterogeneous Systems. Herman N.S. Wiechers (South Africa)	41. The Significance of Stormwater Runoff in an Urbanizing Watershed. Clifford W. Randall, John A. [illegible], Thomas J. Grizzard, Robert C. Hoehn (USA)	42. Treatment Alternatives for Wastewaters from the Tapioca Starch Industry. [illegible] B. Pescod, Nguyen Cong Thanh (Thailand)
9.45 – 10.30 a.m.	Discusser: J. Parker (Australia)	Discusser: F.S. Vivier (S. Africa)	Discusser: A.D. Carr (S. Africa)
	43. Advanced Wastewater Treatment by Chemical Precipitation with Lime and Ammonia Stripping in Ponds. Emanuel Idelovitch, Theo Roth, Nedy Michail (Israel)	44. Prevention and Protection of Sewerage Systems Against Sulphide Attack with Reference to Experience in Singapore. A. [illegible], J. Richardson (Singapore)	45. Process Design Investigations for Alaska [illegible] Mill Wastewater Treatment Facilities. Howard Edde, Richard French, Don [illegible], Toshi [illegible] (USA)
11.00 – 11.45 a.m.	Chairman: H. Caspers (Fed. Rep. Germany) Reporter: G. Rincke (Fed. Rep. Germany) Discusser: A. Wachs (Israel)	Chairman: L.R.J. van Vuuren (S. Africa) Reporter: H.C. Stegmann (S. Africa) Discusser: E.J. Hall (S. Africa)	Chairman: C.J. Price (Australia) Reporter: R.C. Williams (Australia) Discusser: F.E. Neytzell-de Wilde (South Africa)
	46. Improvement of Tertiary Filtration Efficiency by Upgrading Biological Activity. G.M. Faup, J.L. [illegible], J.C. Jacquart (France)	47. The Forecasting of Sulphide Build-up Rates in Sewers. Richard D. Pomeroy, John D. Parkhurst (USA)	48. Measurement and Treatment of Oil and Grease in Petroleum and Petrochemical Industrial Wastewaters. Carl F. [illegible], Richard L. [illegible] III Davis L. Ford (USA)
11.45 – 12.30 p.m.	Discusser: W.W. Eckenfelder (USA)	Discusser: G.E. Eden (UK)	Discusser: B. [illegible] (France)

NOTES

WEDNESDAY AFTERNOON

	HALL A	HALL B	HALL C
2.30– 2.45 p.m.	47. Recirculation Ponds – Pilot Plant and Field Studies. Gedaliah Shelef, Moshe Kremer, Moshe Ernster (Israel) Chairman: L. Coin (France) Recorder: M.A. Baud (France) Discusser: J. Barnard (S. Africa)	50. Current Status of Research in Automation of Wastewater Treatment in the United States. Joseph F. Roesler, Dolloff F. Bishop, Irwin J. Kugelman (USA) Chairman: W. von der Emde (Austria) Recorder: C. Adams (USA) Discusser: W. von der Emde (Austria)	51. Pollution Control Regulations and Monitoring Technology: A Review of Research and Development from the Pulp and Paper Industry. Derek V. Ellis (Canada) Chairman: G. Shelef (Israel) Recorder: To be Announced Discusser: B. Hultman and S. Fr[illegible] (Sweden)
2.50– 3.05 p.m.	52. Seepage from Oxidation Ponds. Emanuel Idelovitch (Israel) Discusser: J. Barnard (S. Africa)	53. A comparison of Pure Oxygen and Diffused Air Digestion of Waste Activated Sludge. David B. Cohen (Canada) Discusser: W.W. Eckenfelder (USA)	54. Biomonitoring with Fish: An Aid to Industrial Effluent and Surface Water Quality Control. William S.G. Morgan (South Africa) Discusser: J. Cairns (USA)
3.30– 3.45 p.m.	55. An Integrated High Rate Pond-Algae Harvesting System. Joseph C. Dodd, John L. Anderson (Australia) Discusser: W.J. Oswald (USA)	56. The Dynamic Behaviour of an Anaerobic Digester. A.D. Carr, R.C. O'Donnell (South Africa) Discusser: H. Schoenberger (Fed. Rep. Germany)	57. The Use of Distance [illegible] Chemiluminescence in Water Quality Monitoring. V.A. Garten, R.B. Head, R. [illegible], J.R. [illegible] (Australia) Discusser: C. Gomella (France)

NOTES

THURSDAY MORNING

	HALL A	HALL B	HALL C
	Workshop – Water Resource Quality Management **Convener: W.K. [illegible]**	**Workshop – Land Treatment** **Convener: A. [illegible]**	
9.00– 10.30a.m.	Recorder: D.J. Lane (Australia) Speakers: 1. P.W. Higgins (Canada) Lakes and Impoundments 2. L.B. Wood (UK) Rivers and Estuaries 3. H. Schmidt (Fed. Rep. Germany) Underground Water 4. M.R. Henzen (S.A.) Acid Mine Drainage	Recorder: B. Lynam (USA) Speakers: 1. C.E. Pound (USA) a) Rational basis for design of land disposal systems b) Long-term effects of infiltration of wastewater into soils 2. I.P. Hunter Land disposal of intractable effluents 3. A. Cottone Storage Capacity of Soils for wastes of too industrial farming 4. J.B. McPherson (Australia) Effluent irrigation for fodder production The basic concepts of land and grass filtration of effluents	
	58. Development of a Rapid Fish Toxicity Test Utilizing a Freeze Concentration Technique for Routine Petroleum Refinery Wastewater Monitoring. **E.C. Birchard (Canada)**	**59. Removal of Organics in Sewage and Secondary Effluent by Reverse Osmosis.** **Edward S.K. Chian, Sheng S. Cheng, Frank B. DeWalle, Powell P.S. Fang (USA)**	**60. Theory and Design of High-Rate Media Trickling Filters.** **Jan A. Oleszkiewicz (Poland)**
11.00– 11.45a.m.	Chairman: M.R. Henzen (S. Africa) Recorder: P.E. Odendaal (S. Africa) Discusser: J. Cairns (USA)	Chairman: B.B. Berger (USA) Recorder: D. Sutton (USA) Discusser: M.A. Basti (France)	Chairman: H. Jones (Australia) Recorder: N. [illegible] (Australia) Discusser: J. Roberts (Australia)
	61. Compounds Toxic to Fish in Pulp Mill Waste Streams. **J.M. Leach, A.N. Thakore (Canada)**	**62. Series Intermittent Sand Filtration to Upgrade Wastewater Lagoon Effluent.** **David W. Hill, James H. Reynolds, Steve E. Harris, D.S. Filip, E.J. Middlebrooks (USA)**	**63. Biological Rotating Disc Scale-up Design: Dissolved Oxygen Effects.** **W.R. Chesner, A.H. Molof (USA)**
11.45– 12.30p.m.	Discusser: W.S.G. Morgan (S. Africa)	Discusser: G. Shelef (Israel)	Discusser: G. Rincke (Fed. Rep. Germany)

NOTES

THURSDAY AFTERNOON

	HALL A	HALL B	HALL C
	64. Nitrification in Free-Flowing Streams. Fernando F. Lopez-Bernal, Peter A. Krenkel, Richard J. Ruane (USA)	65. Ion Exchange in a Moving Bed of Magnetized Resin. B.A. Bolto, D.R. Dixon, A.J. Priestley E.A. Swinton (Australia)	66. Uptake of Americium-241 by Algae and Bacteria. Julia P. Giesy, Jr., Donald Paine (USA)
2.00– 2.40 p.m.	Chairman: A. Van Haute (Belgium) Recorder: J. Babin (France) Discusser: J. Gerhard (U.K.)	Chairman: T. Tsutsui (Japan) Recorder: M. Hiraoka (Japan) Discusser: A.D. Carr (S. Africa)	Chairman: P.A. Krenkel (USA) Recorder: A. Sato (Japan) Discusser: J. Slade (UK)
	67. Consideration of the Efficiency of Attached Organisms in the Simulation of Self-Purification and Oxygenation Capacity of Flowing Waters. Peter Wolf (Germany)	68. Recovery of Zinc using Chelating Resin. Hiroyuki Uejima, Masahiro Hino, Tadasu Ishikawa (Japan)	69. Nutrient Exchange Kinetics in Water Sediment Interface. Calvin P.C. Poon (USA)
2.40– 3.20 p.m.	Discusser: K. Papadopoulos (Fed. Rep. Germany)	Discusser: R.K. Chalmers (UK)	Discusser: W. Stumm (Switzerland)
	70. Comparison of Semi-Continuous and Continuous Flow Bioassays. James H. Reynolds, E.J. Middlebrooks, D.B. Porcella, W.J. Grenney (USA)	71. Water Demineralization by a Thermally Regenerable Ion Exchange. B.A. Bolto, N.H. Pilkington, P.W. Sharples, G.K. Stephens, K.O. Wade, D.E. Weiss (Australia)	72. Mercury Transport Interacting with Bed Sediment Movement. Akira Kudo, D. Ron Townsend, Donald R. Miller (Canada)
3.20– 4.00 p.m.	Discusser: D. Bruere (N. Zealand)	Discusser: F.G. Neytzell-de Wilde (South Africa)	Discusser: T. Sumi, T. Morioka (Japan)

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Appendix II

ASSIGNMENTS

Participants in USANC Report on Developments at IAWPR Sydney Conference

SESSION	18th Monday	19th Tuesday	20th Wednesday	21st Thursday
A-1 (Hall A, 9-10:35 am	Farooq[*]	Pearson	Weber[*]	Canham
A-2 (Hall A, 11-12:35 pm	↓	Cairns[*]	↓	Pomeroy
A-3 (Hall A, 2-4:35 pm	Malina	Reynolds	Lockwood	Hanes
B-1 (Hall B, 9-10:35 am	Novotny[*]	Ford	Bogert[*]	Lance
B-2 (Hall B, 11-12:35 pm	↓	Baumann[*]	↓	Baumann[*]
B-3 (Hall B, 2-4:35 pm	Larson	Zoltek	Eckenfelder	Molof
C-1 (Hall C, 9-10:35 am	Giesy[*]	☒	Adams[*]	☒
C-2 (Hall C, 11-12:35 pm	↓	Lynam	↓	Poon
C-3 (Hall C, 2-4:35 pm	Speece	Chian	Edde	Cairns[*]

[*] 2 Sessions

UNITED STATES OF AMERICA NATIONAL COMMITTEE
For representation of the United States to the
INTERNATIONAL ASSOCIATION ON WATER POLLUTION RESEARCH

Chairman
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September 29, 1976

MEMORANDUM

TO:

FROM: Richard I. Dick, Chairman

SUBJECT: Assignments for Development of USANC Report on Sydney Conference

The Coordinating Subcommittee for preparing USANC's analysis of developments at the IAWPR Conference at Sydney has met to determine the sessions to be covered by participants in the project. Your assignment is to prepare a penetrating analysis of developments at the following session:

Date: ________________

Hall: ________________

Time: ________________

The Committee apologizes that the expressed preferences of all participants for particular sessions could not be accommodated.

As soon as you recover from your travel to Sydney, it is essential that you contact one of the members of the USANC Coordinating Subcommittee for the

EPA Report. The members are:

Bernard Berger
Richard Dick
Richard Engelbrecht
David Stephan

The purpose of contacting them is: (1) to verify your presence in Sydney, and (2) to obtain detailed instructions for preparing your section of USANC's report.

The Subcommittee appeals for your understanding because the new form of the EPA grant and the late award of the grant require development of new procedures under tight time constraints. The Subcommittee is still working on the guidelines for report preparation which will be distributed in Sydney, but you can anticipate the following major items:

(1) Penetrating Analyses! - If EPA desired a totally objective and passive assessment of developments at the Conference, they would buy the Conference Proceedings for far less than they are paying us! Interpretation of the significance of developments and inclusion of insights gained outside of the formal meeting rooms is essential.

(2) Timely Submission! - A tight deadline for report submission (probably November 22) will be imposed. The value of our report to EPA diminishes rapidly with time.

(3) Follow the Directions! - We'll be supplying some guidelines on format--please help the Subcommittee by following them.

(4) No Performance, No Money! - USANC's proposal to EPA indicated that we would reimburse only those participants who submit an acceptable report on time.

(5) Have Fun! - While some rigorous guidelines must be imposed, they are not incompatible with the normal objectives of attendance at a research conference.

I look forward to seeing you in Sydney.

ks

Appendix IV

GUIDELINES
on
PREPARATION OF INDIVIDUAL REPORTS
on
DEVELOPMENTS AT THE EIGHTH INTERNATIONAL CONFERENCE ON WATER POLLUTION RESEARCH, SYDNEY

October 17-23, 1976

Emphasis of Report

USANC's report to EPA on developments at the IAWPR Conference in Sydney is not intended to be simply a record of the Conference. Instead, an interpretive analysis of significant developments at the Conference is required. This penetrating assessment is to be developed not only by critical analysis of papers and formal and informal discussions at the technical sessions, but also by inclusion of insights gained through more informal contacts with Conference participants.

The positive aspects of Conference developments should be emphasized (what did you learn that is important to American water pollution research activities?). Don't dwell on criticism of papers which you feel to be inferior, and don't give much space to papers which are not pertinent to problems in the United States.

Distribution

The report will be distributed at least within EPA, to USANC Sponsoring Organizations and USANC committee members, and to participants in the report development. Bylines will be included to acknowledge the authorship of of individual sessions.

Length

Individual reports on sessions are to be as short or long as necessary to adequately describe pertinent developments. It is not necessary to give equal time to each paper. Space in the report should be allocated on the basis of relevance to American water pollution control problems and water pollution research activities. It is anticipated that the average length of individual session reports will be a tightly written 6 to 10 double-spaced pages, but don't unnecessarily expand or condense a concise, penetrating report merely to achieve that length.

Format

The organization and content of the individual reports is to be as indicated in the outline included as Attachment I. Note that the last section of the report provides an opportunity to record observations which do not relate to your assigned session and that it should begin on a separate sheet of paper. These contributions from all participants will be combined.

Metric units should be used, and the editorial standards for Water Research (included as Attachment II) should be observed.

Submission

Individual reports are to be submitted in double-spaced typed finished form. Reports are to be submitted by November 22, 1976 to:

Richard I. Dick
Department of Civil Engineering
University of Delaware
Newark, Delaware 19711

Compensation

Compensation will be on the basis of statements for services and expenses. As indicated in earlier correspondence, no reimbursement for international travel can be allowed, and a maximum level of reimbursement based on available funds, cost sharing requirements (grant based on 70% cost sharing), and the demands on available funds will be established. Reimbursement will be dependent upon receipt of an acceptable report prior to the deadline. Furthermore, because the maximum allowable level of compensation will depend on the magnitude of the total requests for compensation, no payments can be made until all reports are approved (one individual may hold up all payments). Requests for reimbursement are to be sent to the USANC Secretary-Treasurer, R. S. Engelbrecht, at the same time the report is submitted. Use the expense voucher included as Attachment III for this purpose.

Coordinating Subcommittee

Development of these guidelines, review and acceptance of individual reports and preparation of the final EPA report is being coordinated by a U. S. A. National Committee Coordinating Subcommittee consisting of:

Bernard Berger
Water Resources Research Center
University of Massachusetts
Amherst, Massachusetts 01002
Phone: (413)545-2842

Richard Dick
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Environmental Protection Agency
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Phone: (513)684-4439

Additional information concerning this USANC activity may be obtained from any of the Subcommittee members.

OUTLINE FOR INDIVIDUAL REPORTS ON DEVELOPMENTS AT SYDNEY IAWPR CONFERENCE

*I. SESSION

  *A. Day, Hall, Time

  *B. Theme of Session (a few words describing the major orientation of papers--e.g., "Marine Disposal" or "Sludge Thickening and Dewatering")

*II. REVIEWER

  *A. Name

  *B. Position and Affiliation

*III. REVIEW OF SESSION

  *A. Formal Papers

  *B. Prepared Discussions

  *C. Floor Discussions

  *D. Other Observations and Comments Regarding Papers (Insights developed outside of the meeting room, possible sources of additional information, etc.)

*IV. CRITIQUE OF SESSION (Critically review the items in III, indicating matters such as how the research reports were received, their originality and quality)

*V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES (How might the reported results be applied to solve U. S. water pollution control problems? What research pertinent to U. S. needs is suggested by the reported research?)

*VI. INFORMATION AND OBSERVATIONS FROM THE CONFERENCE RELEVANT TO WATER POLLUTION RESEARCH BUT UNRELATED TO ASSIGNED SESSION (Pertinent information on global water pollution control research which was not presented at any of the formal sessions at the Conference.)

(Section VI will be separated from the remainder of the individual reports--place on a separate sheet which includes your name.)

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*These headings are to be contained in each report

ATTACHMENT 11

SCRIPT REQUIREMENTS

1. An original typed copy in double spacing and two copies should be submitted. The text must be ready for printing, and any substantial changes in proof other than typographical errors may be charged to the authors.

2. Half-tone illustrations should be restricted to the minimum necessary and the photographs may be on glossy not matte paper, enlarged sufficiently to permit their clear reproduction in half-tone. These must accompany the manuscript, preferably mounted on separate sheets. If words or numbers appear on photographs two copies are requested, one clearly printed and the other without inscription. If line drawings are already well drawn, it may be possible to reproduce them direct from the original, but in this case it is essential that the original drawings or good photo-prints should be provided. It is not possible to reproduce from "dyeline" prints or from prints with weak lines, and illustrations for reproduction should normally be about twice the final size required. All illustrations should be provided with descriptive legends and the illustrations should accompany manuscripts separately, with legends typed on a separate sheet. The manuscript and diagrams will be discarded one month after publication unless the publisher is requested to return original material to the author.

3. In the interests of economy and in order to avoid the introduction of errors, tables will be reproduced by photo-offset means directly from the authors' manuscripts. In case of difficulty please consult the Photoreprographic Unit of your institution.

(a) Look at current Tables in the Journal, and arrange your spatial layout of the Table to conform.

(b) Type should be clear and even, either on an electric typewriter with a carbon ribbon, or LETRASET.

(c) Tables, headings and legends should be typed on a separate sheet.

(d) Insert rules.

(e) Words normally italicized should be typed in italics or underlined.

4. References to published literature should be quoted in the text as follows: Smith (1950)—the date of publication, in parentheses, following the author's name. References should be listed together at the end of each paper and not given as footnotes. They should be arranged in alphabetical order (first author's surname) with the name of the periodical abbreviated in the style of the *World List of Scientific Periodicals* (4th edn, Butterworths, London, 1963–1965, 3 vols) and appear as follows:

Fermi E. and Marshall L. (1947) On the interaction between neutrons and electrons. *Phys. Rev.* **72**, 1139–1146.
Thring M. W. (1957) *Air Pollution*, p. 132. Butterworths, London.

It is particularly requested that (a) authors' initials (b) title of the paper and (c) the volume or part numbers and page numbers both beginning and end are given in every case.

5. Papers should be without unnecessary historical introduction.

ATTACHMENT III

USANC
REIMBURSEMENT REQUEST

Expenses incurred relating to preparation of interpretive analysis of the 8th Biennial International Water Pollution Control Conference, Sydney, Australia, October 17-23, 1976.

ITEM	AMOUNT[***]	REIMBURSEMENT REQUESTED[***]	REIMBURSEMENT APPROVED
Professional Services (collection/ assimilation/analysis of information, report preparation, etc.) ____ days @ $_______ per day			
Conference Registration[*]			
Subsistence During Conference[*] ____ days @ _______ per day			
Travel Costs[*] --Within U.S.A. --International[**]			
TOTAL			

[*] Attach receipts (subsistence receipts required only if amount exceeds 51 U.S. dollars per day

[**] No international travel costs are reimbursable

[***] Information needed for cost sharing

____
Signature

____
Social Security Number

For Coordinating Subcommittee Use Only:

Report Received (Date) ____________________

Report Accepted and Reimbursement Approval (Date ____________________

Date and Amount Paid ____________________

Send the Voucher To:

Richard S. Engelbrecht
Department of Civil Engineering
University of Illinois at
Urbana-Champaign
Urbana, Illinois 61801